APPENDIX J

TECHNICAL MEMORANDUM #6

City-Wide Sanitary Servicing Master Plan Update: Technical Memorandum 6 - FINAL

Model Design and Development Manual

Prepared for:
City of Waterloo

Prepared by:
Stantec Consulting Ltd.

Project No. 1611 11191

February 6, 2015

Sign-off Sheet

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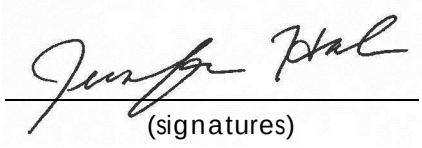
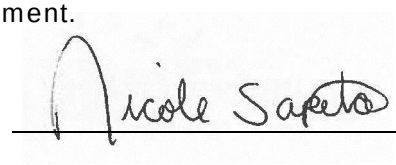
Prepared by  

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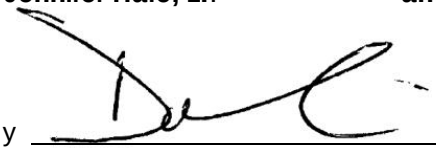
Reviewed by 

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Table of Contents

1.0 BACKGROUND 1.1

2.0 MODEL PHILOSOPHY 2.1

3.0 METHODOLOGY 3.1
3.1 PHYSICAL MODEL ELEMENTS 3.1
3.1.1 Sanitary Sewer Network 3.1
3.1.2 Subcatchments 3.3
3.1.3 Pump Stations 3.5
3.2 DRY WEATHER FLOWS 3.5
3.2.1 Population Data 3.6
3.2.2 Baseline Flow (Groundwater Infiltration) 3.9
3.2.3 Average Dry-weather Sewage Flow 3.9
3.2.4 External Contributions 3.10
3.3 WET WEATHER FLOWS 3.13

4.0 CALIBRATION AND VALIDATION 4.1
4.1 CALIBRATION CHALLENGES 4.1
4.1.1 Flow Splits (Pipe Bifurcation) 4.1
4.1.2 Flow Monitors in Series 4.2
4.1.3 Flow Monitor Location and Pipe Size Discrepancies 4.2
4.1.4 Flow Monitor Data Quality 4.2
4.1.5 Wet Weather Flow Calibration 4.3
4.2 APPLICABLE FLOW MONITORS 4.3
4.2.1 Selection of Suitable Dry Weather Days 4.6
4.3 DRY WEATHER CALIBRATION AND VALIDATION 4.7
4.3.1 Monitor CBA-12 (FM-001) 4.10
4.3.2 Monitor FWL-4A (FM-002) 4.10
4.3.3 Monitor GLN-4 (FM-003) 4.11
4.3.4 Monitor LEE-9 (FM-004) 4.11
4.3.5 Monitor LEX-8A (FM-005) 4.11
4.3.6 Monitor LRL-56 (FM-006) 4.12
4.3.7 Monitor LWD-6 (FM-007) 4.12
4.3.8 Monitor KEA-30 (FM-008) 4.12
4.3.9 Monitor MPL-63 (FM-009) 4.12
4.3.10 Monitor L31-3 (FM-010) 4.12
4.3.11 Monitor UNI-4 (FM-011) 4.13
4.3.12 Monitor LRL-19 (FM-012) 4.13
4.3.13 Monitor WLM-1B (FM-013) 4.13
4.3.14 Monitor FWL-22 (FM-014) 4.14
4.3.15 Monitor FWL-50 (FM-015) 4.14
4.4 WET WEATHER CALIBRATION AND VALIDATION 4.14
4.4.1 Selection of Suitable Rainfall Events 4.14

4.4.2 Calibration Overview 4.16
4.4.3 Monitor CBA-12 (FM-001) 4.19
4.4.4 Monitor FWL-4A (FM-002) 4.20
4.4.5 Monitor GLN-4 (FM-003) 4.20
4.4.6 Monitor LEE-9 (FM-004) 4.20
4.4.7 Monitor LEX-8A (FM-005) 4.20
4.4.8 Monitor LRL-56 (FM-006) 4.21
4.4.9 Monitor LWD-6 (FM-007) 4.21
4.4.10 Monitor KEA-30 (FM-008) 4.21
4.4.11 Monitor MPL-63 (FM-009) 4.21
4.4.12 Monitor L31-3 (FM-010) 4.21
4.4.13 Monitor UNI-4 (FM-011) 4.22
4.4.14 Monitor LRL-19 (FM-012) 4.22
4.4.15 Monitor WLM-1B (FM-013) 4.22
4.5 PARAMETERS FOR NON-MONITORED SUBCATCHMENTS 4.22
4.5.1 Pump Station Comparison 4.23

5.0 RECALIBRATION ALONG THE FORWELL TRUNK 5.1
5.1.1 Selection of Suitable Dry Weather Days 5.1
5.2 DRY WEATHER RECALIBRATION AND VALIDATION 5.2
5.2.1 Monitor FWL-50 (FM-015) 5.3
5.2.2 Monitor FWL-22 (FM-014) 5.3
5.2.3 Monitor FWL-4A (FM-002) 5.3
5.3 WET WEATHER RECALIBRATION AND VALIDATION 5.5
5.3.1 Selection of Suitable Rainfall Events 5.5
5.3.2 Recalibration Overview 5.6

6.0 SANITARY SYSTEM ASSESSMENT 6.1
6.1 MODEL LIMITATIONS AND APPLICATION 6.1
6.2 METHODOLOGY 6.1
6.2.1 Level of Service Criteria 6.1
6.2.2 Design Storm Event 6.2
6.3 CURRENT STATE MODEL RESULTS 6.3
6.3.1 Dry Weather Modeling Results 6.3
6.3.2 Wet Weather Modeling Results 6.5

7.0 FUTURE MODEL SCENARIOS 7.1
7.1 FUTURE DRY WEATHER FLOWS 7.1
7.1.1 Future Population Data 7.1
7.1.2 Future Sewage Per Capita Rates 7.4
7.1.3 Future Baseline Flow (Groundwater Infiltration) 7.4
7.1.4 Future External Flows 7.4
7.2 FUTURE WET WEATHER FLOWS 7.8
7.3 FUTURE SCENARIO MODEL RESULTS 7.8
7.3.1 Dry Weather Modeling Results 7.8

7.3.2 Wet Weather Modeling Results 7.13
7.4 ON-GOING CALIBRATION 7.17
7.5 PROCESS FOR UPDATING MODEL 7.17
7.5.1 Loading Data 7.17
7.5.2 Editing Attributes 7.19
7.5.3 Scenario Management 7.21
7.5.4 Interpreting Results 7.24
7.6 NEXT STEPS 7.33

LIST OF TABLES

Table 3.1: Pump Stations 3.5
Table 3.2: Populations used for Existing-State Model Calibration 3.6
Table 3.3: Flow Contributions from Stockyards Area 3.11
Table 4.1: Applicable Sanitary Flow Monitors for Calibration 4.3
Table 4.2: Selected Dry Weather Days 4.6
Table 4.3: Dry Weather Flow Parameters 4.7
Table 4.4: Dry Weather Calibration/Validation Results 4.8
Table 4.5: Wet Weather Calibration/Validation Rainfall Events 4.16
Table 4.6: Wet Weather R-T-K Parameters 4.16
Table 4.7: Wet Weather Calibration/Validation Results 4.17
Table 4.8: Comparison of SCADA Data and Modeled Pump Station Flows 4.23
Table 5.1: Selected Dry Weather Days 5.2
Table 5.2: Dry Weather Flow Parameters 5.2
Table 5.3: Dry Weather Calibration/Validation Results 5.4
Table 5.4: Wet Weather Recalibration/Validation Rainfall Events 5.5
Table 5.5: Wet Weather R-T-K Parameters 5.6
Table 5.6: Wet Weather Calibration/Validation Results 5.6
Table 7.1: Future Populations for Planning Horizons 2014, 2019, and 2024 ..... 7.3
Table 7.2: Leachate Generation Rates for Planning Horizons 7.6
Table 7.3: Design Flows for Stockyards Area 7.6
Table 7.4: Summary of Point Loads for Large Users 7.7
Table 7.5: Falconridge PS Current and Future Capacity Estimates 7.8

LIST OF FIGURES

Figure 3.1: Sanitary Drainage Network 3.2
Figure 3.2: Sanitary Subcatchment Areas 3.4
Figure 3.3: Off-Campus Student Population Distribution 3.7
Figure 3.4: On-Campus Student Population Distribution 3.8
Figure 3.5: External Contributions 3.12
Figure 4.1: Flow Monitors in Series 4.2
Figure 4.2: Sanitary Calibration Flow Monitor Locations 4.5
Figure 4.3: Comparison of Cumulative Rainfall at Local Rain Gauge Stations 4.15

Figure 6.1: Definition of Flooding in Separated Sewer Systems 6.2
Figure 6.2: DWF Modeling Results for Calibrated Current State Conditions 6.4
Figure 6.3: WWF Modeling Results for Calibrated Current State Conditions (10-yr, 3 Hr Chicago Storm) 6.7
Figure 6.4: WWF Modeling Results for Calibrated Current State Conditions (25-yr, 3 Hr Chicago Storm) 6.8
Figure 7.1: External Contributions and Large User Flows 7.5
Figure 7.2: DWF Modeling Results for Future 2014 Conditions 7.10
Figure 7.3: DWF Modeling Results for Future 2019 Conditions 7.11
Figure 7.4: DWF Modeling Results for Future 2024 Conditions 7.12
Figure 7.5: WWF Modeling Results for Future 2014 Conditions (10-yr, 3 Hr Chicago Storm) 7.14
Figure 7.6: WWF Modeling Results for Future 2019 Conditions (10-yr, 3 Hr Chicago Storm) 7.15
Figure 7.7: WWF Modeling Results for Future 2024 Conditions (10-yr, 3 Hr Chicago Storm) 7.16

LIST OF APPENDICES

APPENDIX A PHYSICAL MODEL LINK-NODE NETWORK INPUT DATA A.1

APPENDIX B SANITARY CALIBRATION AND VALIDATION B.1

APPENDIX C TOWNSHIP OF WOOLWICH INFLOWS C.1

APPENDIX D SANITARY RECALIBRATION AND VALIDATION OF FORWELL TRUNK D.1

1.0 BACKGROUND

The City of Waterloo (City) has retained Stantec Consulting Ltd. (Stantec) to complete the Waterloo Sanitary Servicing Master Plan Update (Master Plan). The purpose of the Master Plan is to account for increases in population and employment growth projections up to a planning horizon of 2031. Priority and strategic projects will be evaluated to allow the system to continue to efficiently and effectively operate, implement best management practices, and optimize staging of the sanitary capital program.

The following tasks form the basis of the Master Plan:

- Task 1: GIS Sanitary Quality Control and Field Verification - Complete
- Task 2: Hydraulic Needs Assessment - Complete
- Task 3: Hydraulic Model Benefit/Cost Analysis - Complete
- Task 4: Hydraulic Model Development, Train, and Implement
- Task 5: Flow Monitoring and Inflow/Infiltration
- Task 6: Public Consultation
- Task 7: Master Plan

Task 4 is the development and implementation of the hydraulic model to be used in the assessment of existing and future conditions. The purpose of this Tech Memo is to outline the model development process, including the input data sources and the model calibration and validation process. A summary is also provided for the methodology for assessing the performance of the system and procedures for updating the model for future use.

2.0 MODEL PHILOSOPHY

A Model Needs Assessment was conducted as part of Task 2 to determine the level of detail, anticipated use, and preferred functionality of the sanitary model specific to the needs of the City. The outcome of the assessment indicated a dynamic model with a higher than trunk level of detail was preferred.

The preferred approach was to include all trunk and subtrunk sewers in the model. The Core Area is of particular importance as a result of future intensification and aging infrastructure; therefore, all pipes within the Core Area were also included in the model.

The trunk and sub-trunk portion of the model is a skeletonized model which allows for high level decision-making and system planning. The full pipe level of detail in the Core Area allows the model to be used to understand localized conditions that may impact the design for services to accommodate the significant growth in this area. The benefits of this approach include a less onerous calibration processes and more efficient computational times. It can be noted that although a City-wide all-pipe model is not required at this time, it was identified as a long-term goal for the City.

Based on the Model Needs Assessment, the selected modelling platform is PCSWMM. This platform was preferred based to the following considerations:

- Ability to complete dynamic modeling analysis
- Superior calibration and advanced topological tools built into the base cost
- Local software provider to support training and implementation needs
- Excellent vendor availability and extent of customer/technical support
- Economical fee structure, with subscription-based approach allowing annual review of needs

3.0 METHODOLOGY

The hydraulic model has input parameters to represent the physical model elements and the flows that are to be accommodated by the system. The physical system consists of the sanitary sewer network, the subcatchment areas, and the pump stations. The sanitary flows are often broken down into two categories: dry weather flow and wet weather flow. Dry weather flow includes baseline flow (groundwater infiltration) and sewage generation, and wet weather flow includes the dry weather flow and additional inflow and infiltration associated with a storm event.

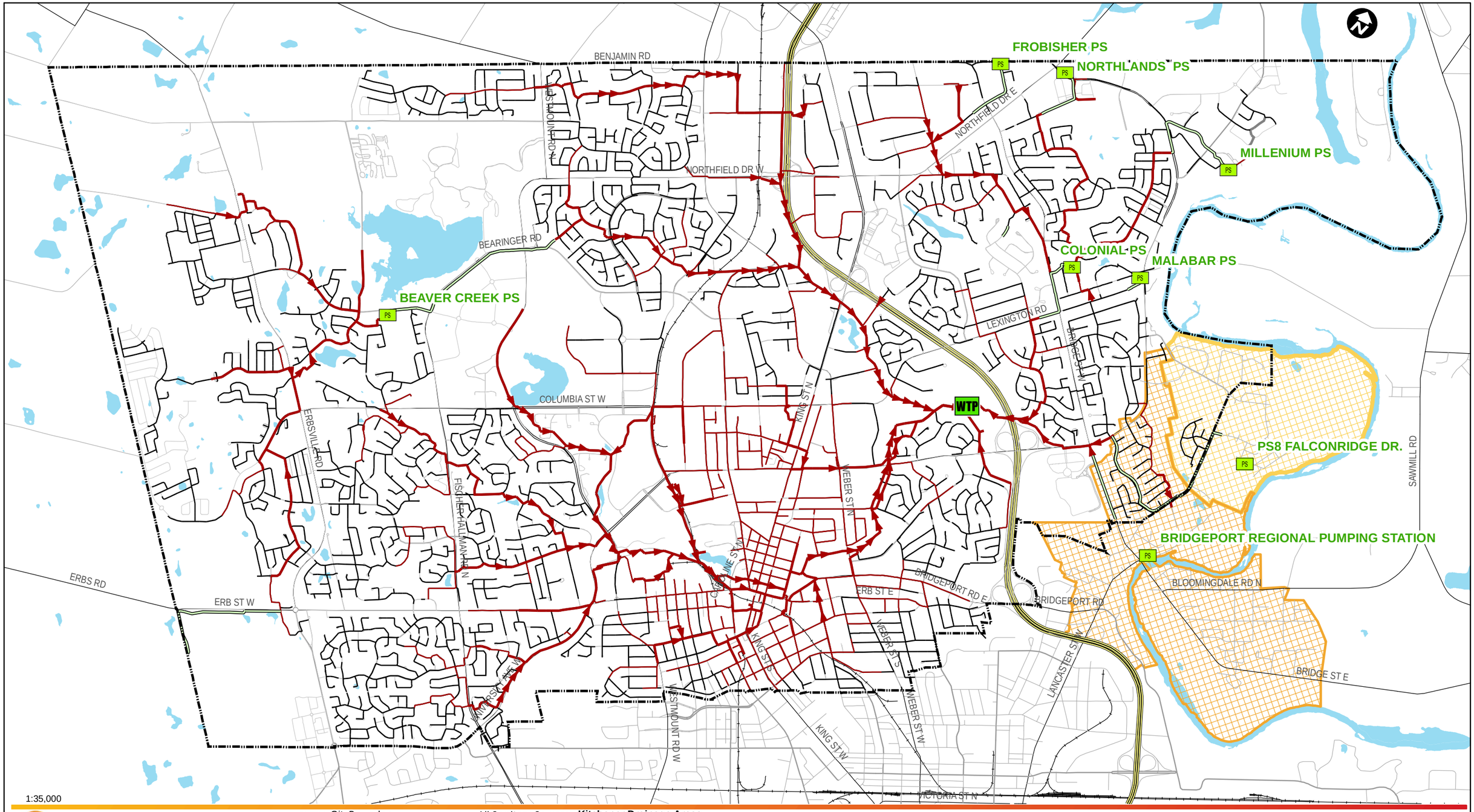
3.1 PHYSICAL MODEL ELEMENTS

The following sections describe the physical model development activities used to build the sanitary system hydraulic model.

3.1.1 Sanitary Sewer Network

The link-node framework was imported from the City of Waterloo's "Current State" geodatabase, with connectivity defined by the up and downstream MXASSET IDs. The engineering validation efforts of *FINAL Technical Memorandum No. 2: GIS Sanitary Quality Control and Field Verification* (Stantec, 2013) assessed the data quality and corrected suspect or missing data based on available drawings and engineering judgement. All data updates were documented in the geodatabase for reference and future follow-up where required. Appendix A can be referenced for details regarding the model input data for the sewers and manholes.

As noted in Section 2.0, a combination of a full pipe model and a trunk level model has been developed. The model includes trunks and subtrunks throughout the City and all pipes (including local sewers) within the Core Area. The full pipe network and the modelled selection set are presented in Figure 3.1 for the sanitary collection system.



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Legend

- CityBoundary
- Water Body
- Forcemain
- PS Existing Pump Station
- WTP Wastewater Treatment Plant

All Sanitary Sewers
- Local Sewers
- Trunk Sewers

Model Selection Set
- Local Sewers
- Trunk Sewers

Kitchener Drainage Areas
- Bridgeport Pump Station
- Falconridge Pump Station

1611-11191

Figure No. FIGURE 3.1

Title SANITARY DRAINAGE NETWORK

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3.1.2 Subcatchments

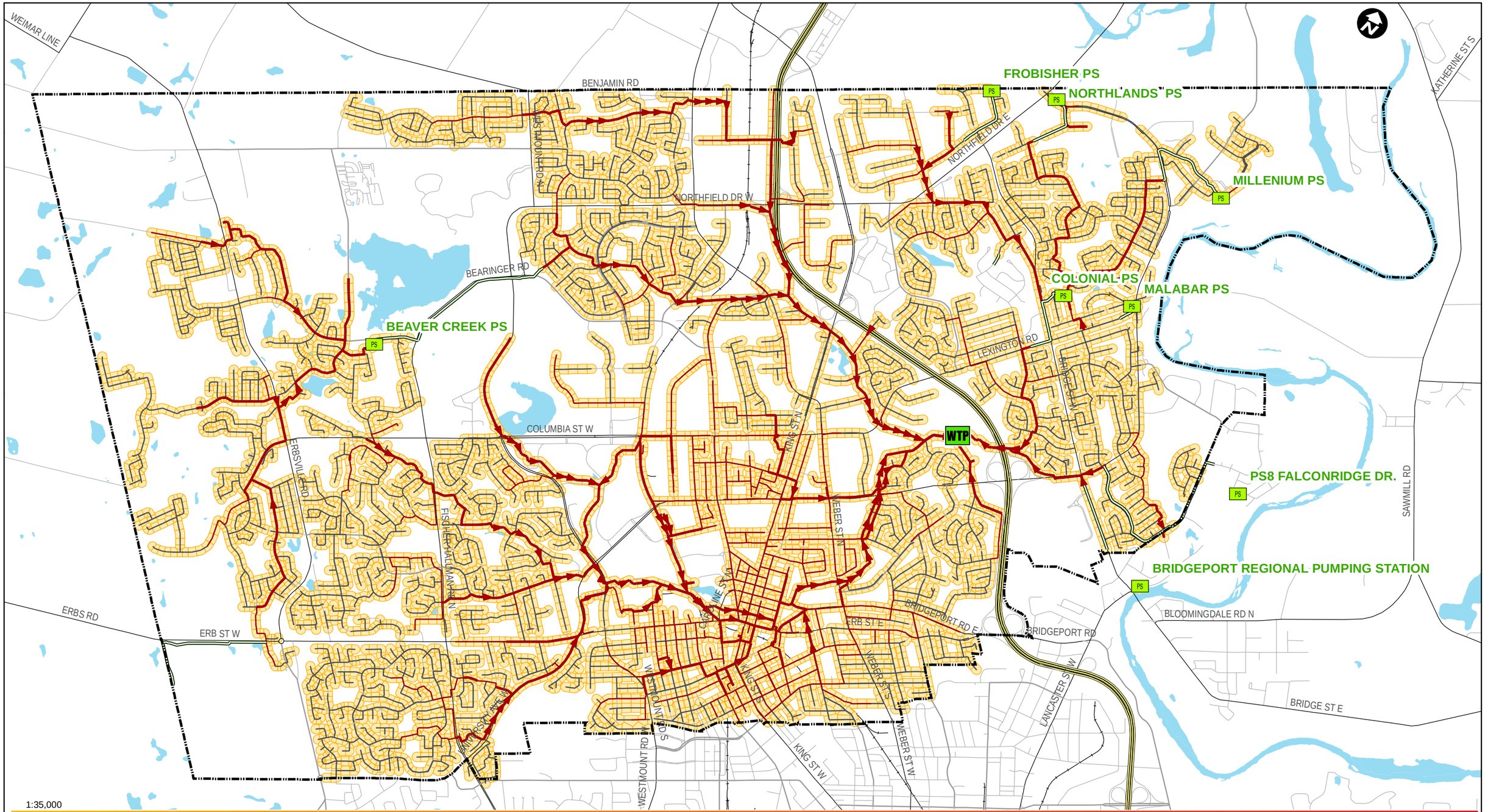
Sanitary subcatchment drainage areas were based on an estimated area of influence associated with the physical sewer drainage network. Initially a 45 m buffer on both sides of the sanitary sewers defined the subcatchment drainage areas. This method prevents the over-estimation of tributary areas, which ultimately defines the fraction of rainfall entering the system and can impact the relative comparison between monitored subcatchments. The buffered subcatchments were further discretized to individual nodes using the built-in Theissen Polygon method outside of the PCSWMM software and manually reviewed to confirm appropriate shape and connectivity to the collection system. Figure 3.2 illustrates the delineation of sanitary subcatchments in the City.

It is noted that two subdivisions, Country Squire Estates and Colonial Estates, are currently on septic system and are not connected to the sanitary collection system. As a result, these locations are excluded from the subcatchment delineation.

The drainage areas for the external contributions beyond the City's municipal boundary were not directly simulated within the model, as the upstream flow is collected at pump stations that regulate discharge into the City's collection system. External contributions to the City's collection system include the following:

- Region of Waterloo Landfill Leachate Pump Discharge (refer to Section 3.2.4)
- Township of Woolwich St. Jacobs Market Area Discharge (refer to Section 3.2.4)
- City of Kitchener Sanitary Pump Stations (refer Section 3.2.4)

The physical subcatchments form the basis for associating municipal address points to the sewer network, as described in Section 3.2 (Dry Weather Flow). As noted above, the subcatchment areas also impact the fraction of rainfall that enters the system in the hydraulic model.


WEIMAR LINE
BENJAMIN RD
KATHERINE ST S
FROBISHER PS
NORTHLANDS PS
MILLENIUM PS
COLONIAL PS
MALABAR PS
BEAVER CREEK PS
PS8 FALCONRIDGE DR.
BRIDGEPORT REGIONAL PUMPING STATION
WTP
ST LAURENT BLVD
NORTHFIELD DR W
NORTHFIELD DR E
BEARINGER RD
LEXINGTON RD
BRIDGEPORT RD W
COLUMBIA ST W
ERBSVILLE RD
FISHERHALLMAN RD N
KING ST N
WEBER ST N
ERB ST W
ERB ST E
BRIDGEPORT RD E
BLOOMINGDALE RD N
SAWMILL RD
ERBS RD
WESTMOUNT RD S
KING ST S
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Sanitary Subcatchment Areas
All Sanitary Sewers
Local Sewers
Trunk Sewers
Model Selection Set
Local Sewers
Trunk Sewers
1611-11191
Figure No. FIGURE 3.2
Title SANITARY SUBCATCHMENT AREAS
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3.1.3 Pump Stations

There are six pump stations within the City of Waterloo and two pump stations in the City of Kitchener that contribute flow to the Waterloo network. A list of the pump stations is provided in Table 3.1 and the location of each pump station is displayed in Figure 3.1.

Table 3.1: Pump Stations

Pump Station Name	Owner
Beaver Creek	City of Waterloo
Colonial	City of Waterloo
Frobisher	City of Waterloo
Malabar	City of Waterloo
Millenium	City of Waterloo
Northlands	City of Waterloo
Bridgeport	Region of Waterloo
Falconridge/Melitzer	City of Kitchener

All pump stations within the City boundaries were represented in the model as a storage unit (wet well), all pumps at the station, and a forcemain. Information for the stations was collected from available As Recorded drawings, design reports, and SCADA data (2011 through 2013). Model input parameters included wet well storage curves, wet well floor elevation, estimated pump curves, pump operating levels, forcemain diameter, and forcemain length. It can be noted that the PCSWMM model uses the Hazen-Williams equation to calculate the capacity of forcemains, and a roughness C-factor of 130 was assumed for all forcemains.

The pump stations located outside the City boundaries (Falconridge and Bridgeport) had less detailed information available; therefore, they were represented in the model as direct inflows based on flow monitoring or SCADA data (see Section 3.2.4).

3.2 DRY WEATHER FLOWS

A dry weather period is defined by the absence of precipitation and the only two components of flow are sewage generation and baseline flow. The sewage generation flow at a given location is based on the upstream population and an equivalent per capita rate. Population data was provided by the City and sewage per capita rates were estimated based on flow monitoring data and calibration efforts. Baseline flow was determined using flow monitoring data to define a generation rate per unit area within the subcatchment. The following sections provide a summary of the data sources and methodology used to determine the model input data for dry weather flows.

3.2.1 Population Data

Population data has been categorized into residential, employment (ICI), and student populations (On Campus and Off-Campus). The population for each category was derived from separate sources, as a consolidated source with all data was not available. Detailed spatial allocation of the populations was not provided in the source files; therefore, the population was distributed based on assumptions discussed within this section. The City-wide populations for each category are summarized in Table 3.2.

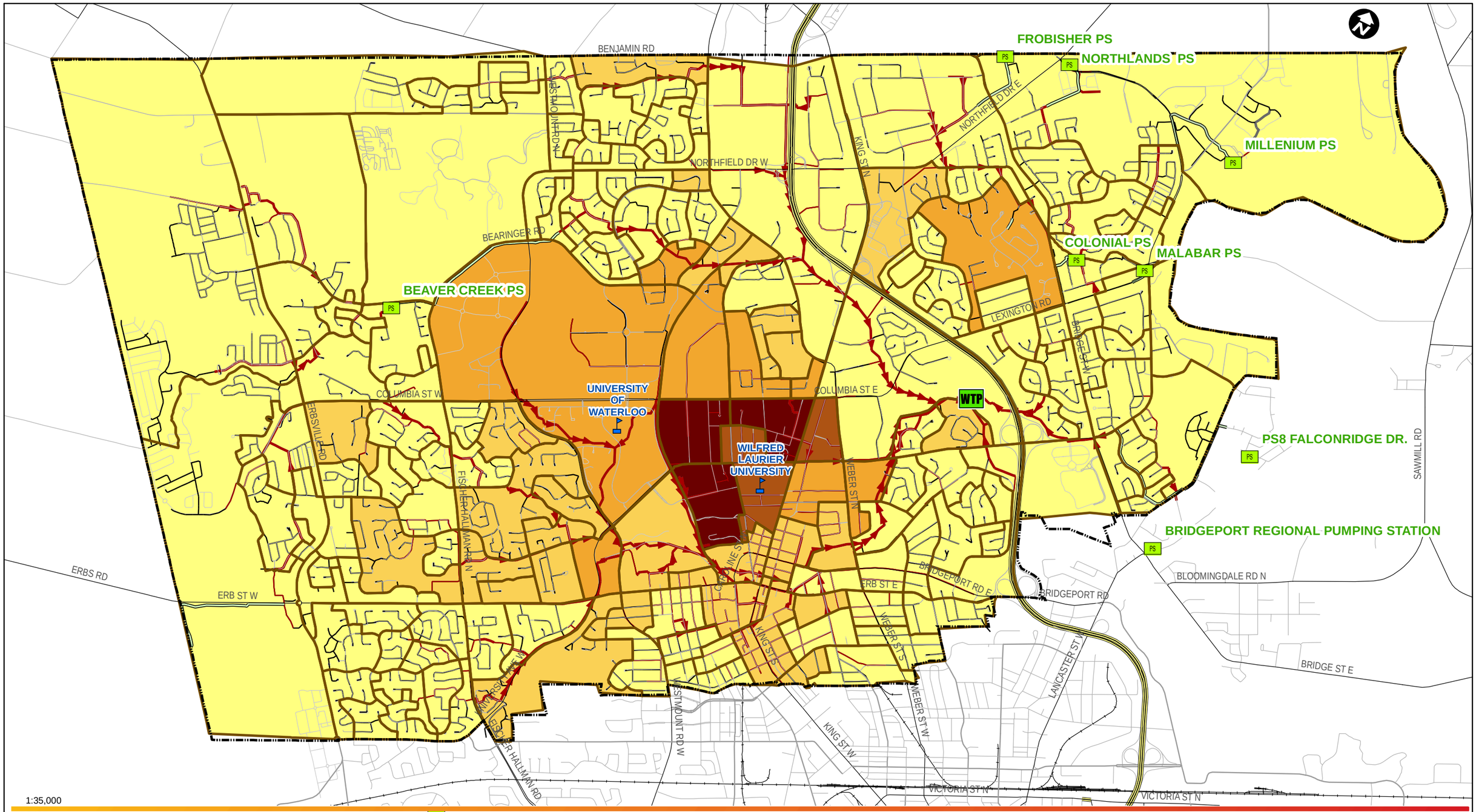
Table 3.2: Populations used for Existing-State Model Calibration

Residential	Off-Campus Students	On Campus Students	Employment
98,681	16,944	4,828	63,473

An estimate of the residential population was provided for Dissemination Areas (DA) based on the 2011 Census data. Individual residential land parcels were then identified based on MPAC codes and the stormwater rate classification fields. Within each Dissemination Area, the population was spatially allocated based on the weighting of the 2012 water consumption records. For example, the percent of an individual billing record to the total water consumption within a DA was used to distribute the DA residential population to the corresponding parcel. This method allocates higher populations to heavy water users and lower populations to light water users.

The total employment population is based on the 2011 National Household Survey (a portion of the 2011 Census) results. Spatial allocation was not provided for this data (i.e. population by Dissemination Area); therefore, the population was allocated to ICI properties and weighted by water consumption records across the entire City. The MPAC codes and Stormwater codes were used to identify the ICI properties.

The student population is not captured within the Census; therefore, the student population provided in the Development Charges Background Study (Hemson, 2012) was added to the residential population. DAs with unusually high water consumption per capita rates based on the Census residential population were identified and assumed to have artificially low populations due to the omission of students. The Off-Campus student population (16,944) was applied to these Dissemination Areas, which reduced the per capita water consumption rate to a maximum of 201 L/c/d (previously up to 1619 L/c/d). Figure 3.3 illustrates the distribution of the off-campus student population.



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Legend

Transportation Network
- Arterial
- Collector
- Highway
- Local
- CityBoundary

- PS Existing Pump Station
- Forcemain
- WTP Wastewater Treatment Plant
- University Campus

All Sanitary Sewers
- Local Sewers
- Trunk Sewers

Model Selection Set
- Local Sewers
- Trunk Sewers

Off-Campus Student Population (No. of Students)
- 0 - 75
- 76 - 270
- 271 - 990
- 991 - 1190
- 1191 - 2081

1611-11191

Figure No. FIGURE 3.3

Title Off-Campus Student Population Distribution

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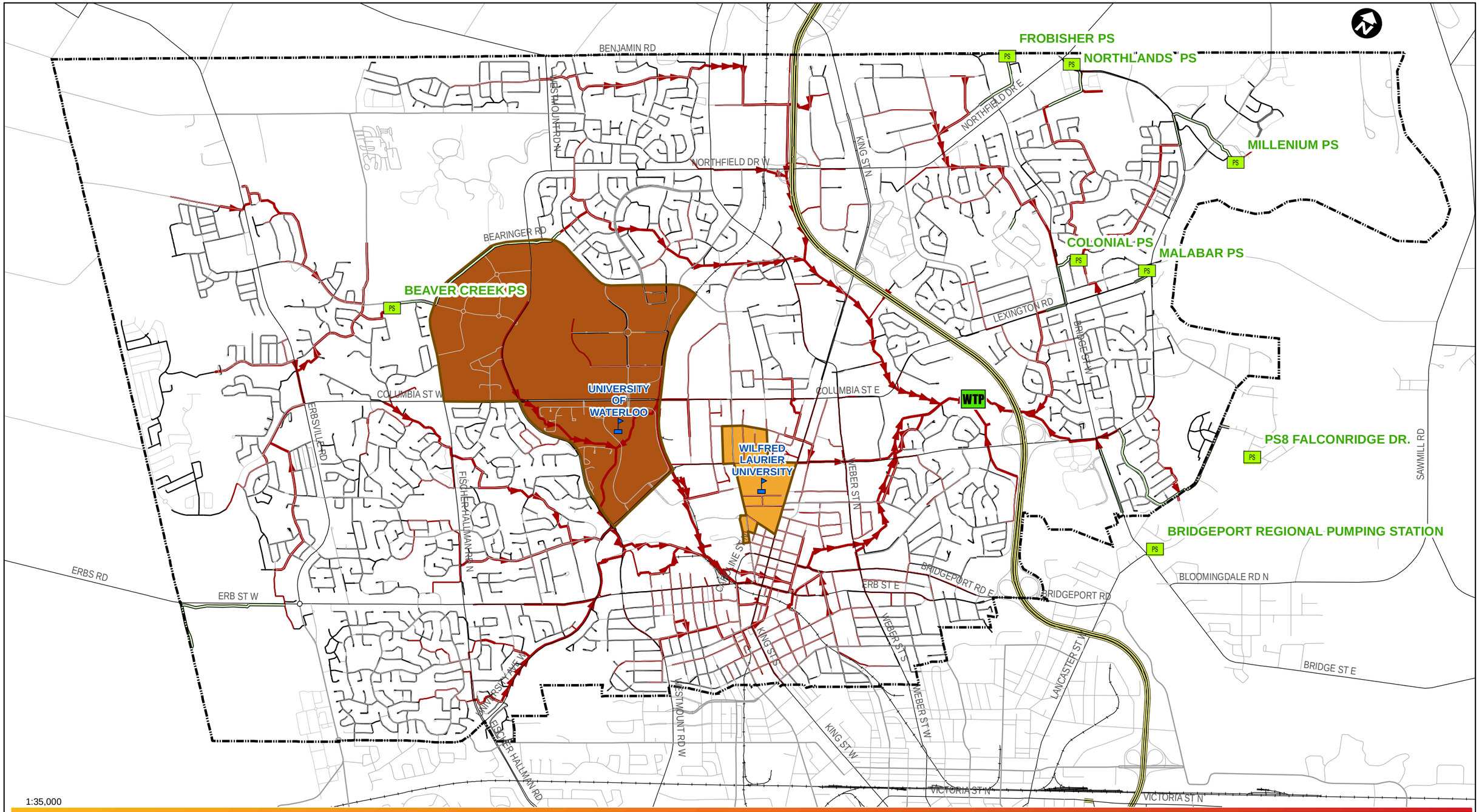

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- University Campus

All Sanitary Sewers
- Local Sewers
- Trunk Sewers

Model Selection Set
- Local Sewers
- Trunk Sewers

On-Campus Students (No. of Students)
- 1281
- 3547

1611-11191

Figure No. FIGURE 3.4

Title On-Campus Student Population Distribution

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On-Campus students were also omitted from the Census data. To account for this population, an On-Campus student population reported by the University of Waterloo[1] and the Wilfred Laurier University[2] were applied to the campus subcatchments. The On-Campus Student populations are summarized in Figure 3.4.

3.2.2 Baseline Flow (Groundwater Infiltration)

The driving input parameters in PCSWMM for dry weather flow are Groundwater Infiltration (GWI) and Average Dry-weather Sewage Flow (ADSF) for each subcatchment. GWI is known as Baseline Flow in the model and represents the assumed constant non-sewage contribution in the system resulting from groundwater leakage at joints, broken pipes, etc. This value was derived from flow monitoring data for each monitored sewershed using the empirical Stevens-Schutzbach method, which is an equation based on a curve fitting technique to capture the low flow hours in the diurnal flow monitoring pattern as follows:

$$GWI = \frac{0.4\ (DWF_{min})}{1 - 0.6(DWF_{min}/DWF_{avg})^{DWF_{avg}{}^{0.7}}}$$

The calculated GWI is normalized by the flow monitoring sewershed area and applied to each sewershed based on the resulting L/s/ha rate. In non-monitored areas, computed values were applied to like-sewersheds based on land use and relative depth of sewer.

3.2.3 Average Dry-weather Sewage Flow

ADSF is applied to the model at the node as an average flow in m^3/s (independent of GWI), which is then multiplied by the 24-hr diurnal pattern. Flow monitoring data was used with population data to generate a per capita flow rate per monitored sewershed. The per capita rates were used to validate in the calibration process to confirm appropriate distribution of population and pipe connectivity. It can be noted that although the population data is an important part of developing the model inputs, it is not a direct input parameter. Diurnal patterns were also derived from the flow monitoring data for weekdays and weekends to capture differences in sewage generation trends. In areas where no flow monitoring coverage existed, data from areas with similar land use characteristics were applied.

Given the desire for future all-pipe model development, the subcatchments, baseline flow and population distributions were conducted at the all-pipe scale, then aggregated to the next receiving node that was modeled in the system.

[1] University of Waterloo. (n.d.). Waterloo Residences. Retrieved July 8, 2014, from University of Waterloo: https://uwaterloo.ca/housing/residences
[2] Wilfred Laurier University. (n.d.). Residential Services. Retrieved July 8, 2014, from Laurier Student Affairs: http://waterloo.mylaurier.ca/residence/info/resbldgs/wluresidences.htm

3.2.4 External Contributions

As noted in Section 3.1.2, the sanitary network receives flows from various sources outside the City's boundaries. Figure 3.5 illustrates the location of the external contributions, which include the following sources:

- Leachate from the Waterloo Waste Management Site
- Inflows flows from the St. Jacob's Farmers Market and Stockyards area
- Inflows from Falconridge and Bridgeport Pump Station (PS) (located in Kitchener)

3.2.4.1 Leachate Inputs

The Region of Waterloo Waste Management Site collects and pumps leachate via Pump Station 3 (PS-3) into the City's Sanitary Network along Ira Needles Blvd. The forcemain from PS-3 discharges to node 15530 (Manhole CH25-18). PS-3 has two pumps, each with a capacity of 7.6 L/s. The current agreement between the Region and the City restricts the discharge to a maximum flow rate of 7.6 L/s of leachate discharge into the City's Network, which implies that the two pumps are not run concurrently. Historic data was provided from 2013 SCADA records including daily volumes of leachate pumped into the City's Sanitary System for 2013. The flow monitoring data from CBA-12 flow monitor, which receives contributions from PS-3, was used to establish an approximate flow pattern for PS-3. The flow pattern was applied to the average daily flows to create a time-series for input to the model.

3.2.4.2 Township of Woolwich Stockyards Area Input

The Stockyards Area includes a portion of the Village of St. Jacobs, and drains into the City of Waterloo Sanitary Network. Three sources of information were used to determine flow inputs for the Stockyards area: peak and baseline flows from the Township of Woolwich (Township) (refer to Appendix C), diurnal patterns from flow monitoring completed in 2011, and the diurnal pattern from the 2013 flow monitoring. The flow monitoring completed in 2011 was upstream of node 15639, and captured the commercial Market area including the Wal-Mart Centre. The properties upstream of node 11908 are residential; the commercial diurnal pattern derived from the 2011 flow monitoring data would not be representative. Therefore the diurnal pattern from the 2013 flow monitoring was applied to node 11908 from the flow monitor FWL-22 (FM-014). As the Township only provided peak and baseline flow, the average flow was back-calculated based on an estimated peaking factor. The peaking factor (2.05) was estimated based on the flow monitoring completed within the St. Jacobs Market Area (Stantec, 2011). Table 3.3 summarizes the flows provided by the Township and the average flows calculated based on flow monitoring. It can be noted that flows have been applied within the model to nodes 15639 (Manhole F38-4B) and 11908 (Manhole F47-1).

Table 3.3: Flow Contributions from Stockyards Area

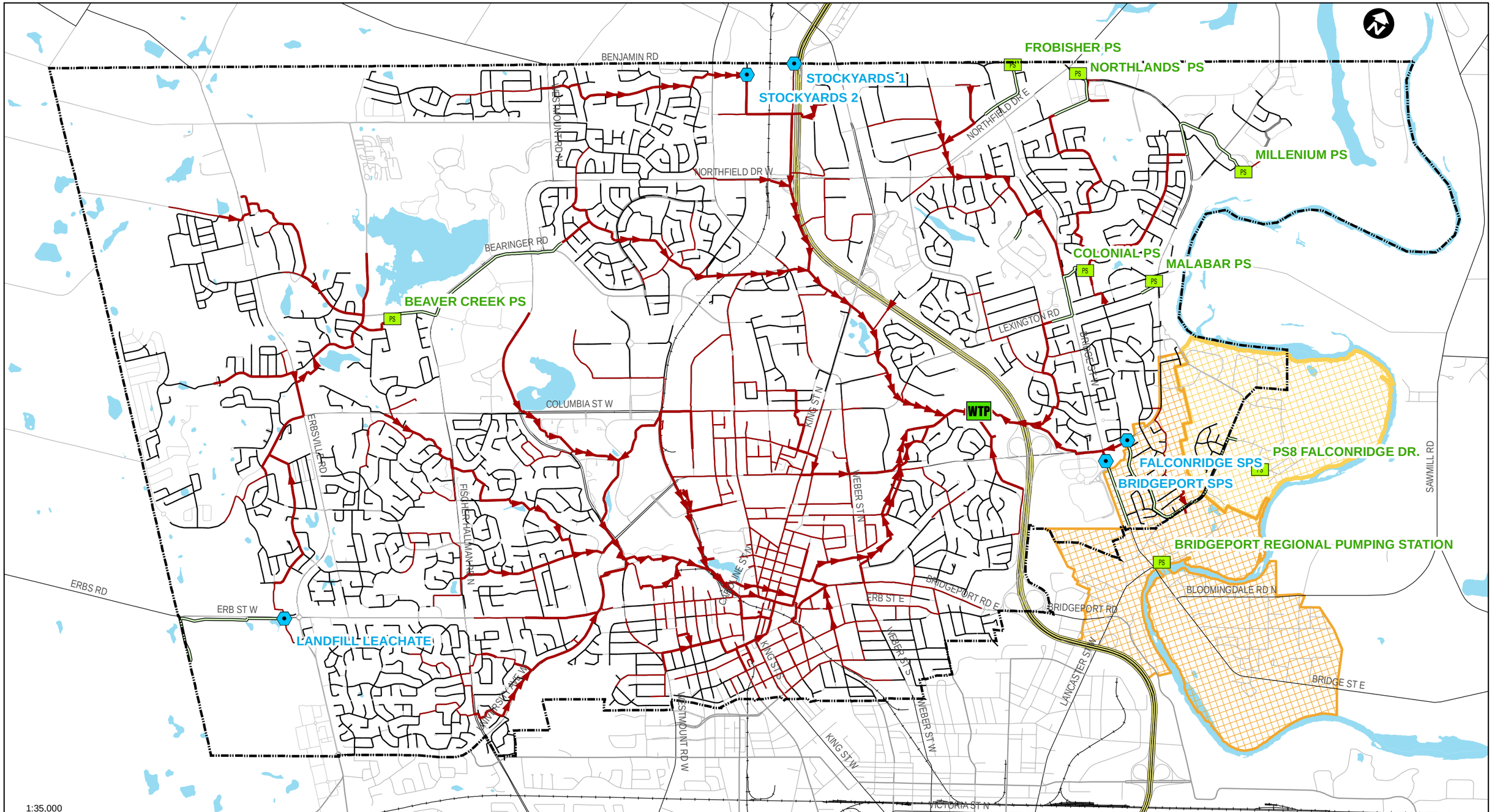
Model Node	Peak Flow (L/s)	Average Flows (L/s)	Baseline Flow (L/s)
MH 15639 (F38-4B)	6.0	2.9	1.2
MH 11908 (F47-1)	4.6	2.3	2.8

3.2.4.3 Bridgeport Pump Station (Region of Waterloo)

The Bridgeport PS is owned by the Region of Waterloo, and is situated within the City of Kitchener. The catchment area is mostly within Kitchener with a small area from Waterloo contributing to the pump station. The Region provided 2013 SCADA records of flows in five minute intervals. The SCADA recorded flows were input into the model as a timeseries of direct sewage inflow at MH 7918 during calibration and validation. The timeseries was used as a model input at this time as full dry and wet weather simulations of the tributary area to Bridgeport is outside the scope of this Master Plan.

3.2.4.4 Falconridge Pumping Station (City of Kitchener)

The Falconridge PS is owned by and situated within the City of Kitchener. The catchment area is mostly within Kitchener with a small area from Waterloo contributing to the pump station. A peak flow of 12.97 L/s was reported for the Falconridge PS in the *City-wide Sanitary Sewer System Capacity Study* completed by AECOM in 2011 for the City of Kitchener. Because SCADA records were not available for the Falconridge PS, a timeseries could not be used. The peak flow of 12.97 L/s as reported in the AECOM report (2011) was applied as an average sewage flow. The diurnal pattern derived from the downstream flow monitor LEX-8A was applied to the average sewage flow, which provides a conservative representation of the forcemain discharge.



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Legend

- CityBoundary
- Water Body
- Forcemain
- PS Existing Pump Station
- WTP Wastewater Treatment Plant

All Sanitary Sewers
- Local Sewers
- Trunk Sewers

Model Selection Set
- Local Sewers
- Trunk Sewers

- External Contributions

Kitchener Drainage Areas
- Bridgeport Pump Station
- Falconridge Pump Station

1611-11191

Figure No. FIGURE 3.5

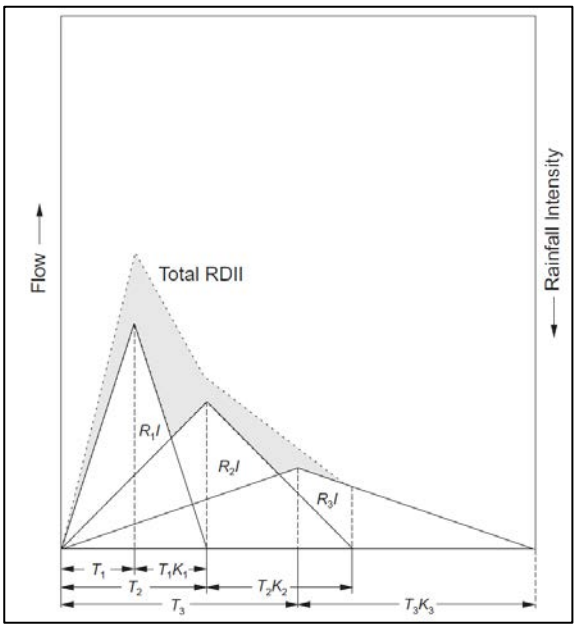
Title EXTERNAL CONTRIBUTIONS

Client/Project CITY OF WATERLOO SANITARY SERVICING MASTER PLAN UPDATE

3.3 WET WEATHER FLOWS

The approach to wet weather flow (WWF) is the use of the widely accepted RTK unit hydrograph method. The RTK method generates the total inflow and infiltration (I/I) into the sanitary sewer system by combining triangular unit hydrographs from three components of flow:

- Rapid inflow (short-term response)
- Moderate infiltration (medium-term response)
- Slow infiltration (long-term response)



The following three parameters describe the shape and volume of runoff that enters the sanitary sewer:

- "R" is the fraction of precipitation that becomes direct inflow
- "T" is the time to peak of the hydrograph
- "K" is the ratio of the recession time to the time to peak

"R" can be equated to the area under the unit hydrograph curve and represents I/I volume per unit area as a fraction of precipitation. The PCSWMM model allows for the direct input of RTK parameters per flow monitoring sewershed. A curve-fitting approach was employed to develop initial input values for the nine RTK parameters, which were then adjusted using the Sensitivity Radio-Tuned Control (SRTC) tool during the calibration process to better represent the historical flow monitoring data for various events.

4.0 CALIBRATION AND VALIDATION

Characteristic dry weather flow (DWF) parameters (sewage generation rate, baseline flow, average diurnal pattern) and wet weather flow (WWF) characteristics (peak flow, peak volume, RTK parameters) are determined for each applicable flow monitoring station, including a comparison with historical data (using Stantec's SFM flow monitoring data analysis software) to ensure overall consistency.

The sanitary model is calibrated and validated to the monitored DWF, considering weekday and weekend flow patterns. The validated DWF sanitary system model is then used to perform the wet weather calibration/validation to monitored WWF events. Parameters were input to the hydraulic model on a trial basis and the routed flow hydrographs produced by the model at each monitor site were compared to the "observed" monitored flow. The parameters were then varied in a systematic manner within a reasonable range until an acceptable fit to the observed flow was obtained. Comparisons were made between modeled versus monitored flow, depth, volume, and velocity. The calibration prioritized representing the peak flow and total flow volume well for each monitoring location, as these parameters are more indicative of potential capacity restrictions. In addition, parameters for velocity and depth typically indicate significant differences between modeled and observed data, as field conditions such as sediment depth, minor defects and obstructions, and actual pipe slope in the vicinity of the flow monitor may vary from modeled conditions.

Calibration included modification to parameters such as sewage generation rates, contributing area characteristics (population, connectivity, etc.), and RTK values. The available flow monitoring data was evaluated in terms of overall data quality and temporal consistency with the other sanitary flow monitors. The preference was to have monitors with common time frames to assess the operation of the sanitary network to better determine the presence of instantaneous outlier data, or spatial variation of rainfall.

4.1 CALIBRATION CHALLENGES

The following describes challenges considered during model calibration.

4.1.1 Flow Splits (Pipe Bifurcation)

Sewer networks often have various manholes with pipe bifurcation where flow may travel into two or more pipes. The exact contribution of flow to a downstream flow monitor is dependent on the characteristics of these splits and their response to varying levels of flow. The upstream catchment of Flow Monitor L31-3 has several instances of bifurcation, which added a degree of uncertainty to the development of calibrated parameters. Without several concurrent monitors in place capturing a large array of flow regimes, the assumed model physical layout must be relied upon.

4.1.2 Flow Monitors in Series

Many areas within the City have flow monitors aligned in series, such that a downstream monitor receives flow from one or more upstream monitors. As part of the calibration process, the most upstream area is calibrated first and subsequent calibrations for downstream areas are based on the difference in areas between the sewersheds. To accomplish this, flows are subtracted for monitors in series to get the associated flow for the difference in areas. There are inherent difficulties introduced when subtracting flow monitors in series due to variations in data quality (stability, variability, drop-outs, etc.) and travel time between monitors. Nonetheless, the use of unique parameters for each area between successive monitors provides increased resolution on both dry weather diurnal patterns and wet weather response.

For each monitor in series, the initial DWF parameter estimation assumed a straight subtraction of average baseline and average daily sewage flow, and used only the tributary area and population between successive monitors to estimate the per capita rate. Flow monitor connectivity for the calibration period is depicted in Figure 4.1.

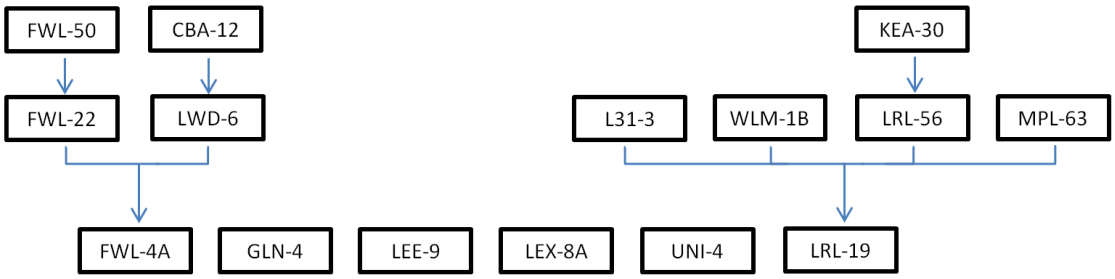


Figure 4.1: Flow Monitors in Series

4.1.3 Flow Monitor Location and Pipe Size Discrepancies

The flow monitoring data was collected under separate assignment by Advanced Monitoring Group (AMG). There were incidents where the pipe size identified by AMG differed from the GIS database. Where the difference was significant, the surrounding pipe profile and available drawings were reviewed to confirm the likely source of error. Where available, assumptions on the exact location of the flow monitor within the sewer pipe were based on field notes and photographs.

4.1.4 Flow Monitor Data Quality

While data from several flow monitors was made available, the raw data reviewed during Task 5 indicated that the quality of data was not consistent between locations. The quality varied for each flow monitor location and time period monitored. In several instances, the flow monitor itself had erratic and unstable depth and velocity readings throughout, and complete velocity or level dropouts. The culmination of these issues is translated into the area-velocity computed

flow which can affect the peak flow and volume that are compared to the calibration simulations. Interpretation of the flow monitoring data was required during calibration to assess the presence of outlier instantaneous spikes or drop-outs, or inconsistencies between calibration and validation periods that could account for discrepancies. Despite variations in the quality of data between flow monitoring locations, the overall data quality was considered adequate for the purposes of calibration.

4.1.5 Wet Weather Flow Calibration

Wet weather calibration has been completed using the RTK method, which is an event based approach. While a uniform set of parameters were developed and applied to each monitored catchment area, in reality, each rainfall event will have their own characteristic RTK relationship. The variability in storm events (i.e. short-duration, high-intensity vs. long-duration, low-intensity) poses a challenge when developing a uniform set of RTK parameters to be applied for all precipitation event, in that the model is not always able to accurately reflect all potential flow responses. For the purposes of this capacity assessment, the RTK parameters have been selected to favour representation of higher-intensity events that are more conducive to generating peak flow response in the system.

4.2 APPLICABLE FLOW MONITORS

A total of 23 flow monitors were installed for various durations throughout 2013 and 2014. Thirteen flow monitors with data in 2013 were used for calibration/validation and an additional two sites with data in late 2013 were used for validation. Table 4.1 and Figure 4.2 summarize the coverage of the sanitary flow monitoring stations used for calibration/validation.

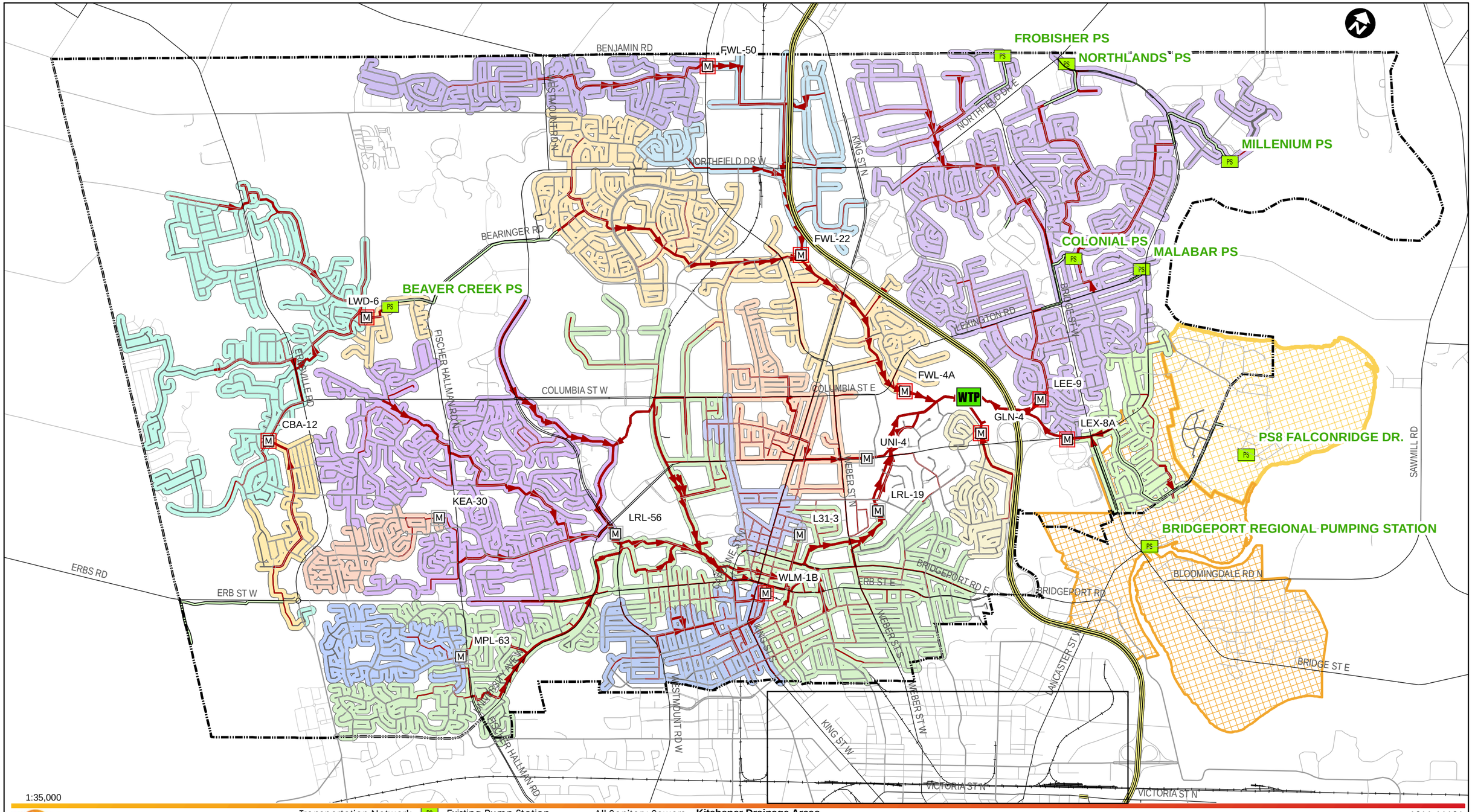
Table 4.1: Applicable Sanitary Flow Monitors for Calibration

Monitor		Start Date	End Date	Drainage Area (ha)	Total Population
City ID	SFM ID				
CBA-12	FM-001	May 14, 2013	January 8, 2014	54.0	2,719
FWL-4A	FM-002	May 15, 2013	January 8, 2014	339.6	18,631
GLN-4	FM-003	May 15, 2013	January 8, 2014	43.5	2,252
LEE-9	FM-004	May 15, 2013	January 8, 2014	546.5	25,980
LEX-8A	FM-005	May 15, 2013	January 8, 2014	776.5 [1]	N/A[2]
LRL-56	FM-006	May 14, 2013	September 16, 2013	352.9	15,708
LWD-6	FM-007	May 14, 2013	January 8, 2014	259.3	10,600
KEA-30	FM-008	December 12, 2012	June 30, 2013	53.9	2,672
MPL-63	FM-009	December 11, 2012	July 17, 2013	78.6	3,296
L31-3	FM-010	December 11, 2012	June 19, 2013	36.3	3,191

Monitor		Start Date	End Date	Drainage Area (ha)	Total Population
City ID	SFM ID				
UNI-4	FM-011	December 12, 2012	July 22, 2013	116.4	13,715
LRL-19	FM-012	December 12, 2012	June 24, 2013	554.0	4,9082
WLM-1B	FM-013	June 25, 2013	January 8, 2014	111.1	6,479
FWL-22	FM-014	October 23, 2013	January 8, 2014	102.0	10,948
FWL-50	FM-015	October 23, 2013	January 8, 2014	131.1	5,505

Note 1: The area presented is estimated, and includes portions of Kitchener and Waterloo which drain into both Falconridge PS and Bridgeport PS (located in the City of Kitchener).

Note 2: Population is unknown for contributing area within Kitchener.



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Legend

Transportation Network
- Arterial
- Collector
- Highway
- Local
- CityBoundary

- PS Existing Pump Station
- Forcemain
- WTP Wastewater Treatment Plant
- M Existing Monitors
- M Existing Monitors (Removed)

All Sanitary Sewers
- Local Sewers
- Trunk Sewers

Model Selection Set
- Local Sewers
- Trunk Sewers

Kitchener Drainage Areas
- Bridgeport Pump Station
- Falconridge Pump Station

1611-11191

Figure No. FIGURE 4.2

Title SANITARY CALIBRATION FLOW MONITOR LOCATIONS

Client/Project CITY OF WATERLOO SANITARY SERVICING MASTER PLAN UPDATE

W:\active\161111191_waterloo_sanitary_mp\preliminary\analysis\gis\mxd\TM6\Fig4.2_Flow Monitor Catchment Areas.mxd

4.2.1 Selection of Suitable Dry Weather Days

Dry weather days were defined as having a maximum of 2.54 mm (0.1 inch) of precipitation. SFM was used to determine intervals of dry weather days, which were then compared against the flow monitors to find monitored dry periods of at least three days. The temporal coverage of each monitor varied; however, dry weather flow periods were selected for calibration to maximize the number of monitors that could be calibrated to the same dry weather period. There were five flow monitors installed in the first six months of 2013, and eight flow monitors installed in the latter portion of 2013. Four dry periods were selected for calibration, such that each flow monitor was installed for two of the DWF periods. As a result of poor data quality, a fifth dry weather period was selected for L31-3. Table 4.2 summarizes the selected periods used for model calibration/validation specific to each monitoring location. To allow for easier reference, each period has been identified by a unique ID (i.e. DWF 1).

Table 4.2: Selected Dry Weather Days

Monitors	DWF 1	DWF 2	DWF 3	DWF 4	DWF 5
CBA-12 (FM-001)	N/A	N/A	July 21-26, 2013	November 21-26, 2013	N/A
FWL-4A (FM-002)	N/A	N/A	July 21-26, 2013	November 21-26, 2013	N/A
GLN-4 (FM-003)	N/A	N/A	July 21-26, 2013	November 21-26, 2013	N/A
LEE-9 (FM-004)	N/A	N/A	July 21-26, 2013	November 21-26, 2013	N/A
LEX-8A (FM-005)	N/A	N/A	July 21-26, 2013	November 21-26, 2013	N/A
LRL-56 (FM-006)	N/A	May 15-19, 2013	July 21-26, 2013	N/A	N/A
LWD-6 (FM-007)	N/A	N/A	July 21-26, 2013	November 21-26, 2013	N/A
KEA-30 (FM-008)	March 3-9, 2013	May 13-19, 2013	N/A	N/A	N/A
MPL-63 (FM-009)	March 3-9, 2013	May 13-19, 2013	N/A	N/A	N/A
L31-3 (FM-010)	March 3-9, 2013	Poor Data	N/A	N/A	April 1-5, 2013
UNI-4 (FM-011)	March 3-9, 2013	May 13-19, 2013	N/A	N/A	N/A
LRL-19 (FM-012)	March 3-9, 2013	May 13-19, 2013	N/A	N/A	N/A
WLM-1B (FM-013)	N/A	N/A	July 21-26, 2013	November 21-26, 2013	N/A

Monitors	DWF 1	DWF 2	DWF 3	DWF 4	DWF 5
FWL-22 (FM-014)	N/A	November 21-26, 2013	N/A	N/A	N/A
FWL-50 (FM-015)	N/A	November 21-26, 2013	N/A	N/A	N/A

4.3 DRY WEATHER CALIBRATION AND VALIDATION

Dry weather flow calibration and validation was completed at all flow monitoring locations, with the exception of FWL-22 and FWL-50. Due to limited available flow monitoring data, these two sites were used for validation only. DWF periods were assigned at each flow monitoring location for the purposes of calibration and validation. For example, at CBA-12 (FM-001) the DWF period from July 21-26, 2013 was assigned as the calibration period and the November 21-26, 2013 was assigned as the validation period.

Table 4.3 presents the resulting dry weather flow parameters, while the calibration results are presented in Table 4.4. Appendix B can be referred to for additional details regarding the calibration and validation process, including goodness of fit plots for the final modeling results.

Table 4.3: Dry Weather Flow Parameters

Monitor	Total Flow (L/s)[1]	Groundwater Infiltration Flow (L/s)	Groundwater Infiltration Rate (L/s/ha)	Average DWF (L/s)	Population	Area (ha)[4]	Observed Per Capita Rate (L/c/d)[2]	Calibrated Per Capita Rate (L/c/d)
CBA-12 (FM-001)	9.8	1.27	0.023	8.5	2,719	55	253	270
FWL-4A (FM-002)	73.7	6.37	0.019	67.3	18,622	334	312	312
GLN-4 (FM-003)	7.2	2.05	0.049	5.1	2,252	42	182	197
LEE-9 (FM-004)	63.8	18.00	0.035	45.8	25,980	516	146	150
LEX-8A (FM-005)	14.1	0.42	0.033[5]	13.7	667	14[6]	N/A[3]	100
LRL-56 (FM-006)	50.2	15.59	0.044	34.6	1,5441	353	194	194
LWD-6 (FM-007)	19.5	4.65	0.018	14.8	10,568	257	121	121
KEA-30 (FM-008)	9.4	3.03	0.059	6.4	2,642	52	250	211
MPL-63 (FM-009)	6.6	2.42	0.032	4.2	3,294	77	94	110
L31-3 (FM-010)	8.6	2.11	0.059	6.5	3,191	36	129	176
UNI-4 (FM-011)	45.4	12.40	0.108	33.0	13,700	115	162	208

Monitor	Total Flow (L/s)[1]	Groundwater Infiltration Flow (L/s)	Groundwater Infiltration Rate (L/s/ha)	Average DWF (L/s)	Population	Area (ha)[4]	Observed Per Capita Rate (L/c/d)[2]	Calibrated Per Capita Rate (L/c/d)
LRL-19 (FM-012)	109.1	12.67	0.023	96.4	48,979	539	125	170
WLM-1B (FM-013)	18.6	4.43	0.042	14.2	6,479	105	189	189
FWL-22 (FM-014)	27.73	6.22	0.059	21.5	10,948	106	130	122
FWL-50 (FM-015)	16.4	2.93	0.023	13.5	5,505	130	213	213

Note 1: Total flow calculated as the sum of the Average DWF and Groundwater Infiltration Flow
Note 2: Observed Per Capita Rate was calculated as the average DWF per capita at a flow monitoring location over the entire monitoring duration. For monitors in series, upstream flow monitor areas, population, and flows were excluded from calculation.
Note 3: Population for Bridgeport PS unknown; observed per capita rate could not be calculated.
Note 4: Excludes upstream areas already captured by separate flow monitors in series.
Note 5: The ground water infiltration rate was set at 0.033 L/s/ha based on rate determined for similar areas. The ground water infiltration rate was not calculated based on flow monitoring data due to uncertainties regarding the contributing areas upstream of Bridgeport PS and Falconridge PS within the City of Kitchener.
Note 6: The reported area only includes the contributing area within the City of Waterloo, and excludes the contributing areas upstream of Bridgeport PS and Falconridge PS.

Table 4.4: Dry Weather Calibration/Validation Results

Parameter	Calibration Results			Validation Results		
	Observed	Simulated	Difference	Observed	Simulated	Difference
CBA-12 (FM-001)	DWF Period: July 21-26, 2013			DWF Period: November 21-26, 2013		
Volume (m^3)	6,327	5,947	-6%	6,033	6,870	14%
Max. Flow (m^3/s)	0.035	0.023	-35%	0.024	0.023	-5%
FWL-4A (FM-002)	DWF Period: November 21-26, 2013			DWF Period: July 21-26, 2013		
Volume (m^3)	78,187	78,458	0%	49,457	77,542	57%
Max. Flow (m^3/s)	0.265	0.236	-11%	0.173	0.236	36%
GLN-4 (FM-003)	DWF Period: July 21-26, 2013			DWF Period: November 21-26, 2013		
Volume (m^3)	3,753	3,720	-1%	3,555	3,715	5%
Max. Flow (m^3/s)	0.017	0.014	-19%	0.017	0.014	-21%
LEE-9 (FM-004)	DWF Period: July 21-26, 2013			DWF Period: November 21-26, 2013		
Volume (m^3)	33,560	33,365	-1%	36,497	33,375	-9%
Max. Flow (m^3/s)	0.125	0.100	-20%	0.124	0.106	-15%

Parameter	Calibration Results			Validation Results		
	Observed	Simulated	Difference	Observed	Simulated	Difference
LEX-8A (FM-005)	DWF Period: July 21-26, 2013			DWF Period: November 21-26, 2013		
Volume (m^3)	19,937	27,634	39%	20,588	27,634	34%
Max. Flow (m^3/s)	0.160	0.089	-44%	0.126	0.089	-29%
LRL-56 (FM-006)	DWF Period: July 21-26, 2013			DWF Period: May 15-19, 2013		
Volume (m^3)	32,142	30,964	-4%	25,467	25,813	1%
Max. Flow (m^3/s)	0.092	0.084	-10%	0.100	0.084	-16%
LWD-6 (FM-007)	DWF Period: July 21-26, 2013			DWF Period: November 21-26, 2013		
Volume (m^3)	14,623	16,054	13%	17,652	16,949	-4%
Max. Flow (m^3/s)	0.049	0.052	6%	0.060	0.049	-18%
KEA-30 (FM-008)	DWF Period: March 3-9, 2013			DWF Period: May 15-19, 2013		
Volume (m^3)	5,868	5,728	-2%	3,885	4,092	5%
Max. Flow (m^3/s)	0.016	0.015	-5%	0.018	0.015	-13%
MPL-63 (FM-009)	DWF Period: March 3-9, 2013			DWF Period: May 15-19, 2013		
Volume (m^3)	3,996	4,003	0%	2,662	2,860	7%
Max. Flow (m^3/s)	0.016	0.014	-10%	0.015	0.014	-4%
L31-3 (FM-010)	DWF Period: March 3-9, 2013			DWF Period: April 1-5, 2013		
Volume (m^3)	4,367	4,590	5%	2,943	3,278	11%
Max. Flow (m^3/s)	0.014	0.011	-21%	0.012	0.011	-10%
UNI-4 (FM-011)	DWF Period: March 3-9, 2013			DWF Period: May 15-19, 2013		
Volume (m^3)	24,860	27,020	9%	17,646	19,299	9%
Max. Flow (m^3/s)	0.067	0.060	-10%	0.064	0.060	-6%
LRL-19 (FM-012)	DWF Period: March 3-9, 2013			DWF Period: May 15-19, 2013		
Volume (m^3)	116,652	124,631	7%	80,399	89,052	11%
Max. Flow (m^3/s)	0.298	0.288	-3%	0.344	0.288	-16%
WLM-1B (FM-013)	DWF Period: July 21-26, 2013			DWF Period: November 21-26, 2013		
Volume (m^3)	8,147	9,655	19%	11,969	9,653	-19%
Max. Flow (m^3/s)	0.031	0.025	-20%	0.037	0.025	-34%
FWL-22 (FM-014)	DWF Period: N/A[1]			DWF Period: November 21-26, 2013		
Volume (m^3)	N/A	N/A	N/A	19,289	23,315	21%
Max. Flow (m^3/s)	N/A	N/A	N/A	0.083	0.060	-27%

Parameter	Calibration Results			Validation Results		
	Observed	Simulated	Difference	Observed	Simulated	Difference
FWL-50 (FM-015)	DWF Period: N/A[1]			DWF Period: November 21-26, 2013		
Volume (m^3)	N/A	N/A	N/A	8,998	8,537	-5%
Max. Flow (m^3/s)	N/A	N/A	N/A	0.034	0.030	-12%

Note 1: Flow monitoring site used for validation purposes only. No calibration trials were completed.

The flow and volumes for DWF were found to compare well, confirming the pipe connectivity and an acceptable delineation of subcatchment areas. The following sections summarize noteworthy findings of the dry weather calibration for each flow monitor.

4.3.1 Monitor CBA-12 (FM-001)

Model results for Monitor CBA-12 are within close proximity for total volume for the calibration (July 21-26, 2013) and validation (November 21-26, 2013) DWF periods (difference of -6% and 14% respectively). Discrepancies were noted for peak flow rates for this site; however, these were associated with the upstream leachate pump at the Waterloo Waste Management Site. For the calibration period, the peak flow is underestimated in the model by 35%. For the validation period, the peak flows are within closer proximity with the model only underestimating the observed flow by 5%.

Leachate from the Waterloo Waste Management Site is collected and pumped to the collection system via PS-3. Available information indicates there are two pumps at PS-3, each with a capacity of 7.6 L/s. At the time of calibration, an agreement between the Region and the City indicated the maximum pump rate is 7.6 L/s, therefore, it was assumed that the pumps operate in a duty-standby configuration. Based on the discrepancy for peak flow during the calibration period, it may be possible that the pump station is operated at a higher capacity during the flow monitoring period than the maximum stated in the agreement. The leachate pumps primarily impact the CBA-12 monitoring location. Downstream monitors (LWD-6 and FWL-4A) indicate peak flows that are less extreme and the modeled results represent the observed data well.

Recalibration for the leachate pumps operating at a higher flow rate was not considered necessary as the agreement between the Region and the City is currently in the process of being updated. The maximum flow is expected to be increased to 15.2 L/s and is to be used for the purposes of evaluating system conditions in the Master Plan (refer to Section 7.1.4.1 for additional details).

4.3.2 Monitor FWL-4A (FM-002)

Model results for Monitor FWL-4A were considered to be within a reasonable range to the flow monitoring results. The calibration period for this site was selected to be November 21-26, 2013

(rather than July 21-26, 2013) as there were higher flows over this time period. Calibrating to the higher flow period was preferable to provide more conservative modeling results. For the calibration period the peak flow was underestimated in the model by 11% and the difference in volume for modeled and observed data was less than 1%. For the validation period (July 21-26, 2013), the peak flow was overestimated by 36% and the volume was overestimated by 57%. The discrepancy in flows for the validation period was attributed to the difference in seasonal flow pattern. Summer flows, especially in areas influenced by student population, are typically lower than in the Fall/Spring.

4.3.3 Monitor GLN-4 (FM-003)

Model results for Monitor GLN-4 closely matched the flow monitoring data for volume, however, the peak flow was underestimated for both the calibration (July 21-26, 2013) and validation (November 21-26, 2013) periods (difference of -19% and -21%, respectively). A review of the flow monitoring data indicates extreme peaks that are uncharacteristic of dry weather flow patterns. When assuming a five-point running average for the observed flow, the modeled peak flow is more representative, only underestimating observed flow by 5% to 8%.

4.3.4 Monitor LEE-9 (FM-004)

Modeling results for Monitor LEE-9 are within close proximity for total volume for the calibration (July 21-26, 2013) and validation (November 21-26, 2013) DWF periods (differences of -1% and -9%, respectively). Discrepancies were noted for peak flow rates for this site; however, the modeled diurnal pattern closely represented the observed data. The discrepancies in peak flow are attributed to uncertainties regarding the operation of the five upstream pump stations. Calibration was completed based on the information available for the DWF periods identified; however, additional investigation is recommended as part of a future study to confirm the pump operating parameters. Based on the calibration completed to date, while the peak flow is underestimated, the overall dry weather volume closely matches observations.

4.3.5 Monitor LEX-8A (FM-005)

Model results for Monitor LEX-8A overestimate the volume and underestimate the peak flow during both calibration and validation time periods. This catchment has many uncertainties, as it receives flows from both Bridgeport PS (owned by the Region of Waterloo) and Falconridge PS (owned by the City of Kitchener). The characteristics of both the pump stations and their contributing catchment are not well understood, and have been simulated primarily as constant inflows due to lack of tributary information. Characteristic dry weather flow parameters cannot be calculated due to the unknown area and population within the Kitchener portion of the contributing catchment. In addition, the flow monitoring location is immediately downstream of the forcemain discharge, which does not provide insight into average flows, diurnal patterns, and peak responses from wet weather events in the upstream catchment area. As a result, the baseline flow rate was set equal to that of the adjacent LEE-9 catchment. Fortunately, the area affected by this monitor represents a very small portion of the City's collection system. Additional

investigation is recommended as part of a future study to verify the operation of the upstream pump stations, however, the level calibration completed to date was considered acceptable as the firm capacity of the pump station is to be used for evaluating future conditions for the Master Plan (refer to Section 7.1.4.5. for details).

4.3.6 Monitor LRL-56 (FM-006)

Model results for Monitor LRL-56 are within close proximity of the flow monitoring data for both the calibration (July 21-26, 2013) and validation (May 15-19, 2013) periods. The total volume is within -4% and +1% for the calibration and validation periods, respectively. For peak flow, the model is within -10% and -16% for the calibration and validation periods, respectively. It can be noted that this site is under the influence of upstream Monitor KEA-30.

4.3.7 Monitor LWD-6 (FM-007)

Model results for Monitor LWD-6 are within close proximity of the flow monitoring data for both the calibration (July 21-26, 2013) and validation (November 21-26, 2013) periods. The total volume is within +13% and -4% for the calibration and validation periods, respectively. For peak flow, the model overestimates the observed data by 6% and underestimates by 18% for the calibration and validation periods, respectively. It is noted that LWD-6 is downstream of CBA-12. Although the impact on the peak flow is substantially less at LWD-6, the operation of the leachate pumps at the Waste Management Site is still evident in the flow monitoring data at this location.

4.3.8 Monitor KEA-30 (FM-008)

Model results for Monitor KEA-30 match extremely well to the flow monitoring data for both the calibration (March 3-9, 2013) and validation (May 15-19, 2013) periods. The total volume is within -2% to 5%, while peak flow is within -13%. This site contributes to downstream monitors at LRL-56 and LRL-19.

4.3.9 Monitor MPL-63 (FM-009)

Model results for Monitor MPL-63 exhibit a close fit to observed data (March 3-9, 2013, and May 15-19, 2013). The total volume is within 7%, and peak flows are generally underestimated but within 10%. This monitor contributes to the downstream monitor at LRL-19.

4.3.10 Monitor L31-3 (FM-010)

Monitoring data for L31-3 was of poor quality and presented challenges for calibration at this location. An additional DWF Period was identified specifically for this location to evaluate both a calibration and validation series, as only one of the original four periods identified had usable data. In addition, bifurcation locations within the subcatchment in the areas of Albert St. and Hickory St. W. and along Young St. E. increased the level of uncertainty when reviewing this

location. At Albert St. and Hickory St. W., the pipe inverts were offset and hydraulically diverts flow. The upstream population and sewershed area was allocated for this location based on the assumption that all flows would be directed to the sewer with the lowest upstream invert. There was a greater level of uncertainty for the bifurcation location at King St. N. and Young St. E., where the inverts of both downstream pipes where at the same elevation. These bifurcation locations impacted the flow directed to L31-3 and LRL-19. It is noted that L31-3 is within the LRL-19 subcatchment so the impact of the bifurcation locations is localized to these two monitoring sites. It was assumed for the purposes of this study that all of the population and subcatchment area upstream of the bifurcation locations were directed to L31-3.

Given the challenges associated with this location, the model results for Monitor L31-3 were considered to provide an adequate representation of the flow monitoring data.

4.3.11 Monitor UNI-4 (FM-011)

Model results for Monitor UNI-4 match the flow monitoring data for both the calibration (March 3-9, 2013) and validation (May 15-19, 2013) periods well. The total volume is overestimated by 9%, while peak flow is within -10%.

4.3.12 Monitor LRL-19 (FM-012)

Monitor LRL-19 is downstream of five monitored catchment areas: MPL-63, WLM-1B, LRL-56, KEA-30, and L31-3. Calibration was completed for the upstream catchment areas based on the observed data specific to each site, and calibration for LRL-19 focused on the incremental area not captured by the upstream flow monitors. As the incremental area of LRL-19 was large and had various land uses, an intermediate location (Westmount Rd. and Westcourt Pl.) between MPL-63 and LRL-19 was reviewed to compare the modeling results between this study and the 2002 Master Plan (no recent flow monitoring data was available at this location). The initial calibration results indicated a large discrepancy in peak flow between the two models. Further review indicated the land use upstream of the intermediate location was similar to that of MPL-63, and the MPL-63 diurnal pattern had more extreme peaking factors than LRL-19. Based on these considerations, the diurnal pattern for MPL-63 was applied to the incremental area of LRL-19 upstream of the intersection of Westmount Rd. and Westcourt Pl. to better match the flows modeled in the 2002 Master Plan.

Final model results for LRL-19 demonstrate a reasonable match to the flow monitoring data for both the calibration (March 3-9, 2013) and validation (May 15-19, 2013) periods. Total volume is within 11%, and the peak flow ranges from -16 to -3%.

4.3.13 Monitor WLM-1B (FM-013)

Monitor WLM-1B indicated a wide variation in the volume of flows between the calibration (July 21-26, 2013) and validation (November 21-26, 2013) periods. Parameters adjusted to accurately represent one period would result in a significant difference for the other. The final calibrated

parameters resulted in model results that range between -19% to +19%. Peak flow is generally underestimated.

4.3.14 Monitor FWL-22 (FM-014)

Monitor FWL-22 was only available for a short period in the Fall of 2013; therefore, it was used as an additional level of validation for the calibrated FWL-4A parameters. Located upstream of FWL-4A, the data provides insight into whether the overall calibrated parameters for the subcatchment are representative of the more localized flow characteristics.

Modeling results at FWL-22 were considered to provide a reasonable representation of the flow monitoring data for November 21-26, 2013. The total volume is overestimated by 21% and the peak flow is underestimated by 27%. The average sewage generation per capita rate was reduced in an effort to reduce overestimation of volume. It is noted that over the same period, the calibration results at the downstream FWL-4A monitor is within 1% of the total volume and 11% of the peak.

4.3.15 Monitor FWL-50 (FM-015)

Similar to Monitor FWL-22, Monitor FWL-50 was reviewed to provide an additional level of validation. FWL-50 is located upstream of both FWL-4A (calibration and validation site) and FWL-22 (validation site only). This site further refined the review of localized flow characteristics to evaluate whether the calibrated parameters for the overall subcatchment area were representative in this area. No parameters were adjusted based on the comparison of modeling results and flow monitoring data at this location.

The modeled results for Monitor FWL-50 were within close proximity for both total volume and peak flow over the validation period (November 21-26, 2013). The modeled volume is underestimated by 5% and the peak flow is underestimated by 12%. This is similar to model results for Monitor FWL-4A over the same DWF period.

Considering the validation results at FWL-22 and FWL-50, the parameters developed for FWL-4A are considered to provide a reasonable representation of the flows for the Forwell system.

4.4 WET WEATHER CALIBRATION AND VALIDATION

4.4.1 Selection of Suitable Rainfall Events

Wet weather events were specified as those with greater than 15 mm of precipitation. Rainfall data was available from the AMG rain gauge located at the Waterloo Waste Management Site. The accuracy of the AMG rainfall data was verified based other available monitoring locations in the area, including:

- University of Waterloo Campus (maintained by the University of Waterloo)

- Kitchener-Waterloo Airport (maintained by Environment Canada)
- Kitchener City Hall (maintained by the City of Kitchener)

The three validation gauges showed similar rainfall patterns to the AMG rain data, as shown in Figure 4.3.

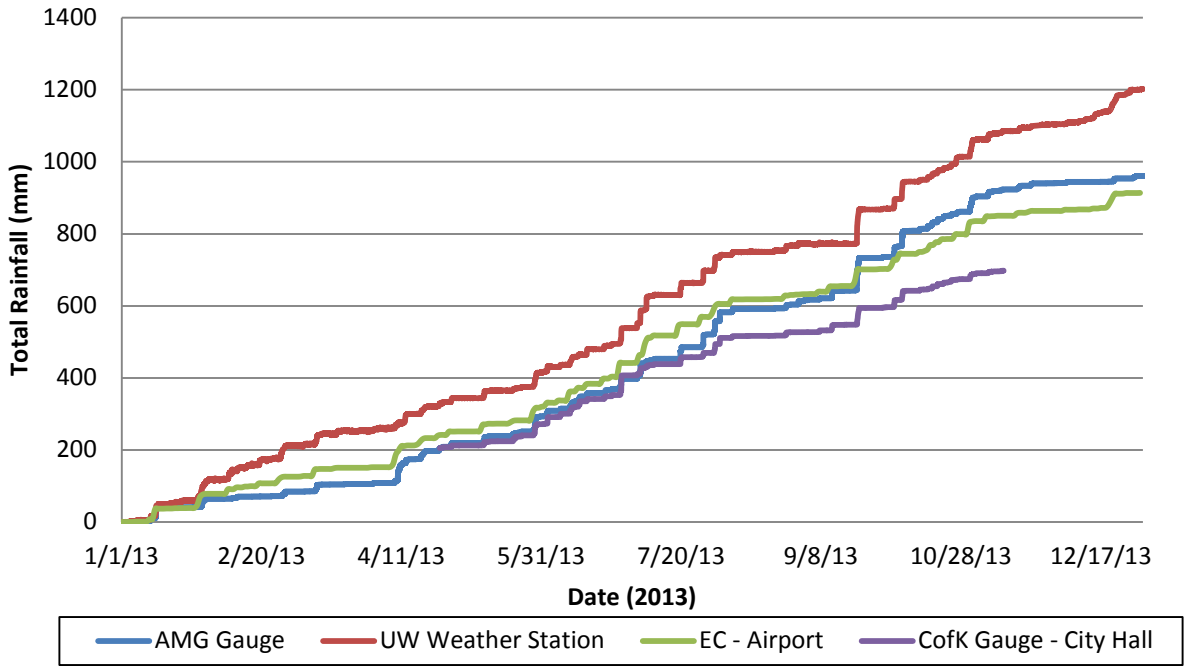


Figure 4.3: Comparison of Cumulative Rainfall at Local Rain Gauge Stations

In general, the UW station tended to show higher rainfall volumes than the other gauges, and the City of Kitchener rain gauge showed lower rainfall volumes. Differences in rainfall volumes at each of the stations can be attributed to spatial variations in the storm event combined with differences in accuracy for various rain gauge technologies. Each of the rain gauges showed similar timing and magnitude for storm events, therefore confirming the validity of the AMG gauge. Overall, 2013 experienced average wet weather conditions.

The model was calibrated to three wet weather events based on storms with a significant depth and the duration of available flow monitoring data (May 28, 2013, June 28, 2013, and July 5, 2013). The peakiest and highest volume rainfall event (September 20, 2013) was selected for validation of the calibrated wet weather parameters. Table 4.5 summarizes the event characteristics for the identified wet weather events.

Table 4.5: Wet Weather Calibration/Validation Rainfall Events

Event ID	Start	End of Rain	Duration[1] (hrs)	Total Rain (mm)	Peak Intensity (mm/5min)	End of WWF Response[2]
WWF 1	5/28/2013 04:00	5/30/2013 15:00	59	41.9	9.1	5/30/2013 18:00
WWF 2	6/27/2013 22:45	6/28/2013 18:45	20	31.6	3.3	6/29/2013 23:00
WWF 3	7/04/2013 05:30	7/05/2013 15:15	34	42.4	9.1	7/06/2013 04:00
WWF 4	9/20/2013 08:45	9/21/2013 12:45	28	89.9	13.7	9/23/2013 08:00

1. Duration based on rainfall event
2. End of observed wet weather response for longest monitored flow, based on hydrograph separation

4.4.2 Calibration Overview

The wet weather response is generated in the model based on RTK input parameters. The initial RTK parameters were derived from flow monitoring response over the identified calibration event, not for the entire wet weather data. It is noted that not all monitors had data for the same time period, and in some cases only one or two of the wet weather events could be used to develop RTK parameters. Where discrepancies for RTK values occurred between calibration events, the peakier event parameters were selected to provide more conservative modeling results. The SRTC tool in PCSWMM was then used to evaluate the variability of each set of RTK parameter per flow monitor, to fine-tune the response.

Table 4.6 presents the resulting wet weather input parameters, while the calibration/validation results are presented in Table 4.7. As noted in Section 4.4.1, the May 28, 2013, June 28, 2013, and July 5, 2013 events were selected for calibration and the September 20, 2013 event was selected for validation.

Table 4.6: Wet Weather R-T-K Parameters

Monitor	R1	T1	K1	R2	T2	K2	R3	T3	K3
CBA-12 (FM-001)	0.008	0.35	35	0.001	12	5	0.001	24	4
FWL-4A (FM-002)	0.025	0.21	28	0.005	12	5	0.001	24	4
GLN-4 (FM-003)	0.020	0.15	35	0.020	10	10	0.010	24	4
LEE-9 (FM-004)	0.010	0.30	38	0.010	7	6	0.010	24	4
LEX-8A (FM-005)	0.020	0.15	35	0.020	10	10	0.010	24	4
LRL-56 (FM-006)	0.012	0.20	30	0.018	12	10	0.007	24	4

Monitor	R1	T1	K1	R2	T2	K2	R3	T3	K3
LWD-6 (FM-007)	0.008	0.32	35	0.001	12	5	0.001	24	4
KEA-30 (FM-008)	0.001	0.20	33	0.005	20.52	20	0.007	24	4
MPL-63 (FM-009)	0.020	0.28	24	0.005	12	5	0.001	24	4
L31-3 (FM-010)	0.001	0.27	75	0.001	12	5	0.001	24	4
UNI-4 (FM-011)	0.030	0.25	20	0.020	12	5	0.001	24	5
LRL-19 (FM-012)	0.003	0.20	46	0.000	22.8	5	0.001	24	4
WLM-1B (FM-013)	0.009	0.20	20	0.005	12	6	0.001	24	4

Table 4.7: Wet Weather Calibration/Validation Results

WWF Event	Peak Flow (m^3/s)			Volume (m^3)		
	Observed	Simulated	Difference	Observed	Simulated	Difference
CBA-12 (FM-001)						
May 28, 2013	0.041	0.025	-40%	3,611	2,534	-30%
Jun. 28, 2013	0.043	0.023	-47%	3,399	2,271	-33%
Jul. 5, 2013	0.056	0.025	-55%	5,833	3,758	-36%
Sep. 20, 2013	0.041	0.027	-34%	5,619	4,250	-24%
FWL-4A (FM-002)						
May 28, 2013	0.257	0.469	82%	21,390	34,070	59%
Jun. 28, 2013	0.458	0.354	-27%	25,860	31,140	20%
Jul. 5, 2013	0.599	0.531	-11%	38,790	47,510	22%
Sep. 20, 2013	0.630	0.655	4%	58,470	57,490	-2%
GLN-4 (FM-003)						
May 28, 2013	0.025	0.027	8%	1,814	1,809	0%
Jun. 28, 2013	0.054	0.018	-67%	2,329	1,629	-30%
Jul. 5, 2013	0.041	0.030	-27%	2,764	2,512	-9%
Sep. 20, 2013	0.029	0.036	23%	2,450	3,296	35%
LEE-9 (FM-004)						
May 28, 2013	0.122	0.162	33%	12,080	15,900	32%
Jun. 28, 2013	0.176	0.144	-18%	14,780	14,420	-2%
Jul. 5, 2013	0.164	0.164	0%	20,890	22,220	6%
Sep. 20, 2013	0.147	0.208	42%	21,220	29,380	38%

WWF Event	Peak Flow (m^3/s)			Volume (m^3)		
	Observed	Simulated	Difference	Observed	Simulated	Difference
LEX-8A (FM-005)						
May 28, 2013	0.155	0.074	-52%	8,449	8,407	0%
Jun. 28, 2013	0.171	0.089	-48%	8,464	9,198	9%
Jul. 5, 2013	0.168	0.105	-38%	11,940	14,330	20%
Sep. 20, 2013	0.141	0.091	-36%	8,444	13,830	64%
LRL-56 (FM-006)						
May 28, 2013	0.102	0.148	45%	11,740	13,470	15%
Jun. 28, 2013	0.175	0.144	-35%	13,210	12,540	-5%
Jul. 5, 2013	0.200	0.165	-17%	20,200	19,240	-5%
Sep. 20, 2013	N/A	N/A	N/A	N/A	N/A	N/A
LWD-6 (FM-007)						
May 28, 2013	0.059	0.066	12%	5,912	6,859	16%
Jun. 28, 2013	0.065	0.058	-11%	5,700	6,285	10%
Jul. 5, 2013	0.072	0.071	-2%	8,549	9,813	15%
Sep. 20, 2013	0.080	0.079	-1%	11,570	11,510	-1%
KEA-30 (FM-008)						
May 28, 2013	0.014	0.016	13%	1,436	1,705	19%
Jun. 28, 2013	0.019	0.015	-18%	1,442	1,689	17%
Jul. 5, 2013	N/A	N/A	N/A	N/A	N/A	N/A
Sep. 20, 2013	N/A	N/A	N/A	N/A	N/A	N/A
MPL-63 (FM-009)						
May 28, 2013	0.023	0.035	51%	1,505	1,912	27%
Jun. 28, 2013	0.038	0.023	-41%	1,887	1,648	-13%
Jul. 5, 2013	0.059	0.038	-34%	2,366	2,518	6%
Sep. 20, 2013	N/A	N/A	N/A	N/A	N/A	N/A
L31-3 (FM-010)						
May 28, 2013	0.009	0.011	30%	857	1,350	58%
Jun. 28, 2013	N/A	N/A	N/A	N/A	N/A	N/A
Jul. 5, 2013	N/A	N/A	N/A	N/A	N/A	N/A
Sep. 20, 2013	N/A	N/A	N/A	N/A	N/A	N/A

WWF Event	Peak Flow (m^3/s)			Volume (m^3)		
	Observed	Simulated	Difference	Observed	Simulated	Difference
UNI-4 (FM-011)						
May 28, 2013	0.069	0.127	85%	7,059	9,745	38%
Jun. 28, 2013	0.277	0.093	-66%	8,249	9,081	10%
Jul. 5, 2013	0.200	0.148	-26%	13,070	13,790	6%
Sep. 20, 2013	N/A	N/A	N/A	N/A	N/A	N/A
LRL-19 (FM-012)						
May 28, 2013	0.361	0.441	22%	33,580	42,250	26%
Jun. 28, 2013	N/A	N/A	N/A	N/A	N/A	N/A
Jul. 5, 2013	N/A	N/A	N/A	N/A	N/A	N/A
Sep. 20, 2013	N/A	N/A	N/A	N/A	N/A	N/A
WLM-1B (FM-013)						
May 28, 2013	N/A	N/A	N/A	N/A	N/A	N/A
Jun. 28, 2013	0.062	0.036	-43%	3,042	3,559	17%
Jul. 5, 2013	0.052	0.052	1%	4,262	5,390	26%
Sep. 20, 2013	0.054	0.059	9%	5,461	6,086	11%

Overall, the wet weather response is replicated well in the model, with some variability between calibration events. This can be attributed to the application of average uniform parameters to differing types of events (e.g. duration, intensity), and is to be expected. For the purposes of this study, the capture of extreme events is considered acceptable, and the calibration/validation process confirms the general pipe connectivity and contributing sewage and wet weather generation rates.

The following sections describe the specific findings of the wet weather calibration for each monitor location, with additional details in Appendix B.

4.4.3 Monitor CBA-12 (FM-001)

Model results for Monitor CBA-12 underestimate the flow for wet weather events. The discrepancy in peak flow is consistent with the DWF calibration, where peak flow was also underestimated due to the operation of leachate pumps at the Waterloo Waste Management Site. This margin of error for DWF would be compounded for the WWF simulations, since the pumps are essentially operating to drain the influence of precipitation on the landfill. Therefore, the difference in peak flow for WWF was considered acceptable based on the information available for calibration.

Total volume is underestimated in the model for CBA-12 for each WWF event. Monitor CBA-12 is upstream of Monitor LWD-6 and FWL-4A, both of which are within close proximity or overestimating the modeled versus observed volume. Therefore, the discrepancy in total volume was considered acceptable for CBA-12, despite being outside the 20% target range for level of accuracy.

4.4.4 Monitor FWL-4A (FM-002)

Model results for FWL-4A are within close proximity for the September 20, 2013 WWF event, with the peak flow within +4% and the volume within -2%. For the June 28, 2013 and the July 5, 2013 events, the peak flow is within -27% and the total volume is within +22%. For the May 28, 2013 event, the model significantly overestimates both peak flow and volume.

As the modeled and observed results were within a reasonable range for the June 28 and July 5, 2013 events, and were within very close proximity for the September 20, 2013 event, the calibrated WWF parameters for FWL-4A were considered acceptable.

4.4.5 Monitor GLN-4 (FM-003)

Model results for GLN-4 indicate a range in discrepancies as flows are overestimated for some WWF events and underestimated for others. The June 28 and July 5, 2013 events underestimate the peak flow by up to 67% and the volume by up to 30%. The May 28 and September 20, 2013 events over estimate peak flow by up to 23% and total volume by up to 35%. The model results for the May 28, 2013 are within the closest proximity to the observed data with the peak flow overestimated by 8% and the volume within 1%.

Given the range in response for the WWF events and the close proximity of results for the May 28, 2013 event, the calibrated WWF parameters for GLN-4 were considered acceptable.

4.4.6 Monitor LEE-9 (FM-004)

Model results for Monitor LEE-9 are within close proximity to flow monitoring data for the July 5, 2013 event. The peak flow is within 1% and the volume is within +6%. Larger discrepancies are noted for the May 28 and September 20, 2013 events; however, the flows in both these cases are overestimated and provide more conservative results. Flow is slightly underestimated for the July 5, 2013 event, however, the peak flow is within 18% and the volume is within 2%. Based on these results, the calibrated WWF parameters for LEE-9 were considered acceptable.

4.4.7 Monitor LEX-8A (FM-005)

As noted for the DWF calibration, there is uncertainty for the LEX-8A subcatchment area as a result of upstream pump stations (Bridgeport PS and Falconridge PS) that service areas of Kitchener. In addition, the wet weather response for the subcatchment areas in Kitchener are not included in the model as the areas are unknown and the pump stations are represented as

point loads in the model. The flow data demonstrates very little response to wet weather, likely attributed to the storage effects of the pump stations. Given these factors, LEX-8A calibration was not considered in detail at this time.

4.4.8 Monitor LRL-56 (FM-006)

Flow monitoring data for LRL-56 is only available for three of the four identified WWF events (May 28, June 28, and July 5, 2013). Generally the wet weather volume is matched well; however, the variability of the rainfall events resulted in an inability to consistently capture the peaks. The site is downstream of KEA-30, which similarly had difficulty in capturing the variability of peak flows.

4.4.9 Monitor LWD-6 (FM-007)

Model results for Monitor LWD-6 match well to flow monitoring data for all WWF events. The discrepancy between modeled and observed peak flow ranges between -1% (September 20, 2013 event) to 12% (May 28, 2013 event). The discrepancy between modeled and observed total volume ranges from -1% (September 20, 2013 event) to 16% (May 28, 2013 event). The upstream influence of CBA-12 is minor to the performance of this location.

4.4.10 Monitor KEA-30 (FM-008)

Flow monitoring data for KEA-30 is only available for two of the four identified WWF events (May 28, and June 28, 2013). Model results are within an acceptable range compared to flow monitoring data for both available WWF events. Similar to the downstream LRL-56, the variability of the events influenced the ability to match peak flows. As elsewhere in the system, peaks are over-estimated for one event, and under-estimated for another.

4.4.11 Monitor MPL-63 (FM-009)

Flow monitoring data for MPL-63 is only available for three of the four identified WWF events (May 28, June 28, and July 5, 2013). Model results indicate a range in discrepancies as flows are overestimated for some WWF events and underestimated for others. Overall, wet weather volume matches well, however, the variability of rainfall intensity, the older nature of the Maple sewershed area, and the potential for private-side foundation drain connections to the sanitary system, render the matches of peaks to all events a challenge.

4.4.12 Monitor L31-3 (FM-010)

Flow monitoring data for L31-3 is only available for one of the four identified WWF events (May 28, 2013). As noted for the DWF calibration, the data quality for this location was poor and there were uncertainties in flow splitting at bifurcation locations.

Even though the R-factor for this location remains low (<0.5%), the May 28, 2013 event still overestimates the peak flow and total volume significantly. Although outside of the target range of 20% for level of accuracy, the modeling results provide a conservative estimate. This may be

an indication that the bifurcation simulated in the model is greater than actually occurs in reality. Given the lack of data to date, it is recommended that the City review CCTV of the upstream/surrounding sewers, or simultaneously monitor several legs of the local system to isolate flow distribution regimes under varying rainfall events. For the purposes of the Master Plan, this area shall be reviewed cautiously in terms of capacity review planning.

4.4.13 Monitor UNI-4 (FM-011)

Flow monitoring data for UNI-4 is only available for three of the four identified WWF events (May 28, June 28, and July 5, 2013). Model results indicate a range in discrepancies as peak flows are overestimated for one WWF event and underestimated for others. Generally, the wet weather volume is captured well.

4.4.14 Monitor LRL-19 (FM-012)

Flow monitoring data for LRL-19 is only available for one of the four identified WWF events (May 28, 2013). It can be noted that WWF parameters for MPL-63 were applied to the incremental area of LRL-19 upstream of University Ave. W. and Erb St. W. This was consistent with the approach for applying DWF parameters, as discussed in Section 4.3.12.

Similar to L31-3 (which is within the LRL-19 subcatchment), flows are overestimated in the model for this event (difference of 22% for peak flow and 26% for total volume) even with a low overall R-Factor applied (<0.5%). The differences in flows are within close proximity to the target range of 20% for level of accuracy and the model results provide a conservative estimate. Therefore, the calibrated WWF parameters for LRL-19 were considered acceptable.

4.4.15 Monitor WLM-1B (FM-013)

Flow monitoring data for WLM-1B is only available for three of the four identified WWF events (June 28, July 5, and September 20, 2013). Model results at monitor WLM-1B overestimate volume for each event, by up to 26%. Peak flow is within close proximity for the July 5 and September 20, 2013 events, which overestimate by 1% and 9%, respectively. For the June 28, 2013 event, the peak flow could not be matched. This is likely a result of additional extraneous or storm contributions entering the system that were not present in the baseline calibration event. In general, the modeled results are within close proximity to observed data and provide a conservative estimate of the volume of flow.

4.5 PARAMETERS FOR NON-MONITORED SUBCATCHMENTS

The flow monitoring data provided coverage for the majority of the City; only a small area near the WWTP did not have coverage. In the absence of monitored data, calibration parameters were assigned to non-monitored subcatchments from a monitored area with similar land use characteristics and vintage of development/sewer pipe. It was determined that LRL-19 was the

best suited to represent the non-monitored subcatchments and the diurnal patterns and RTK parameters were applied.

4.5.1 Pump Station Comparison

Pump station inputs were collected from various sources, as described in Section 3.1.3 and Section 3.2.4. These sources were the best information available at the time of model development and calibration; however, uncertainty remained regarding the detailed inflow and outflows from the pump stations. Many of the pump stations were not in close proximity to a downstream flow monitor; therefore, the simulated pump information was compared to the 2013 SCADA data as an effort to validate the model inputs. Table 4.8 summarizes the observed and modeled data for pump stations within Waterloo based on the May 28, 2012 wet weather flow event.

Table 4.8: Comparison of SCADA Data and Modeled Pump Station Flows

Pump Station	Total Flow (m^3/d)		Maximum Flow (L/s)	
	Modeled	Observed	Modeled	Observed
Beaver Creek	3,610	2,828	100	95
Colonial	4,830	4,196	157	312
Frobisher	103	38	43	34
Malabar	141	1,091	4	46
Millennium	440	156	93	80
Northlands	142	109	95	48

Table 4.8 indicates large discrepancies between modeled and observed data for some pump stations. The largest discrepancy occurs for Malabar PS, where both the total volume and the peak flow were substantially lower than the observed data. A review of the pump curves for Malabar PS indicated that the observed maximum flow (46 L/s) was significantly greater than the operating curve (up to 6 L/s at 15 m TDH). Follow-up is recommended to confirm the operation of this pump station. For the remaining five pump stations, the discrepancy between modeled and observed flows typically provide conservative modeling results as the model overestimates the total and maximum flows. An exception occurs for Colonial PS, where the observed maximum flow was approximately two times the modeled maximum flow. This indicates there are durations where the station operates two pumps online; however, the model only indicates one pump is required. The pump start/stop data provided in 5 minute increments (2012 SCADA data) was reviewed to fine-tune the model start/stop levels; however, the simulations still only requires one pump to be called online. Further investigation is recommended for the three pump stations upstream of Colonial PS to better understand the inflows to the station (Malabar PS, Millennium PS, and Northlands).

As noted in Section 3.2.4, the Bridgeport PS inputs were derived directly from 2013 SCADA data. The SCADA data was compared to the downstream flow monitoring data at LEX-8A, and discrepancies were noted where the pump station discharge was greater than the monitored at LEX-8A. Based on the discrepancy for continuity in flow, calibration in this area was difficult. Although follow-up is recommended, it can be noted that the downstream area impacted within the City is small.

The Falconridge PS inputs were derived from the City of Kitchener Capacity Analysis and Evaluation Report (2011). This station is owned by Kitchener, and although SCADA data was requested for the purposes of this study, it was not available in five minute increments. The closest downstream flow monitor was more heavily influenced by the Bridgeport PS, therefore, there was no opportunity to compare modeled and observed data for this station to validate the operation.

5.0 RECALIBRATION ALONG THE FORWELL TRUNK

Upon completion of the calibration and validation processes, future scenarios were developed for 2014, 2019, and 2024 based on the calibrated DWF and WWF parameters. The initial results for the future scenarios showed significant surcharging along the Upper Forwell Trunk. The extent of surcharging based on the initial results was not reflective of the monitored data for this area; therefore, the wet weather flow modeling parameters for the Upper Forwell Trunk were identified for further investigation to validate the modeling results.

Two flow monitors, located at FWL-22 and FWL-50, were installed in the Upper Forwell Trunk from October 2013 to June 2014. These two monitors are installed in series, as discussed in Section 4.1.2. In the Upper Forwell Trunk, flow monitor FWL-22 receives flow from the upstream monitor FWL-50. In the Lower Forwell Trunk FWL-4A receives flow from both upstream monitors FWL-22 and LWD-6 (upstream of Beaver Creek PS).

At the time of the original calibration, only two months of data were available for flow monitors FWL-22 and FWL-50 and therefore these were not included. Instead, model input parameters for the Upper Forwell Trunk were based on the downstream trunk monitor calibration. For recalibration, approximately six months of data was available at FWL-22 and FWL-50, allowing better resolution for the Upper Forwell Trunk area. Since FWL-22 and FWL-50 discharge through the downstream FWL-4A, the Lower Forwell Trunk was also recalibrated with the available data through April 2014.

5.1.1 Selection of Suitable Dry Weather Days

Dry weather days for the recalibration process were defined using the same methodology as the original calibration process; the maximum precipitation for a dry weather day was set as 2.54 mm (0.1 inch) of precipitation, and a dry weather period was set to have a minimum duration of three days. The temporal coverage of each monitor varied; however, dry weather flow periods were selected for recalibration to maximize the number of monitors that could be calibrated to the same dry weather period. Monitor FWL-4A was installed from May 2013 to April 2014, whereas monitors FWL-22 and FWL-50 were both installed from October of 2013 to June of 2014.

Table 5.1 presents the three dry periods selected for recalibration such that each flow monitor was installed for at least two of the DWF periods.

Table 5.1: Selected Dry Weather Days

Monitors	DWF 1	DWF 2	DWF 3
FWL-4A (FM-002)	July 21-26, 2013	November 21-26, 2013	March 13-28, 2014
FWL-22 (FM-014)	November 21-26, 2013	March 13-28, 2014	N/A
FWL-50 (FM-015)	November 21-26, 2013	March 13-28, 2014	N/A

5.2 DRY WEATHER RECALIBRATION AND VALIDATION

Recalibration and validation under dry weather flow conditions was completed at flow monitoring locations FWL-4A, FWL-22, and FWL-50. The recalibration process focused on the previously un-calibrated FWL-50 monitor, representing the local upstream catchment.

Table 5.2 presents the resulting dry weather flow parameters, while the calibration results are presented in Table 5.3. Appendix D contains additional details regarding the calibration and validation process, including goodness-of-fit plots for the final modeling results.

As part of the recalibration process, the external flows from the Township of Woolwich were reviewed. During the original calibration, the area draining to node 11908 was inadvertently excluded from the model which has now been rectified in the recalibration.

Table 5.2: Dry Weather Flow Parameters

Monitor	Total Flow (L/s)[1]	Groundwater Infiltration Flow (L/s)	Groundwater Infiltration Rate (L/s/ha)	Average DWF (L/s)	Population	Area (ha)[3]	Observed Per Capita Rate (L/c/d)[2]	Calibrated Per Capita Rate (L/c/d)
FWL-4A (FM-002)	73.7	6.37	0.019	67.3	18,622	334	312	312
FWL-22 (FM-014)	22.8	7.36	0.059	15.5	10,948	125	130	122
FWL-50 (FM-015)	16.4	2.93	0.023	13.5	5,505	130	213	213

Note 1: Total flow calculated as the sum of the Average DWF and Groundwater Infiltration Flow
Note 2: Observed Per Capita Rate was calculated as the average DWF per capita at a flow monitoring location over the entire monitoring duration. For monitors in series, upstream flow monitor areas, population, and flows were excluded from calculation.
Note 3: Excludes upstream areas already captured by separate flow monitors in series.

The flow and volumes for DWF were found to compare well, confirming the pipe connectivity and an acceptable delineation of subcatchment areas. The following sections summarize noteworthy findings of the dry weather recalibration for each flow monitor.

5.2.1 Monitor FWL-50 (FM-015)

The focus of the model recalibration was for Monitor FWL-50, as this site is located in the area of concern in the Upper Forwell Trunk that wasn't directly calibrated previously. Although the concern for recalibration was primarily during WWF events, a review of observed data for DWF indicated minor discrepancies in the diurnal patterns when considering the new calibration period (March 13-18, 2014). Therefore, updates were completed for the FWL-50 diurnal pattern to provide a better representation of this time period.

The results were within close proximity for both total volume and peak flow over March 13-18, 2014, and the validation period (November 21-26, 2013), and provided an improvement over the original DWF response at this upstream site.

5.2.2 Monitor FWL-22 (FM-014)

FWL-22 is downstream of FWL-50 which is residential, and receives direct inflow from ICI usage including the external St. Jacobs area. As a result of this change in usage, the observed flow monitoring data indicated frequent fluctuations with extreme peaks. As a result, the model tends to under-estimate the peak flow and over-estimate the total volume. Given the variability in ICI usage, this was considered to be a reasonable representation of flows and no updates were made to the DWF modeling parameters associated with the FWL-22 sewershed area as part of the model recalibration.

5.2.3 Monitor FWL-4A (FM-002)

Modeling results at FWL-4A were considered to be within a reasonable range during the original calibration; however the change in upstream trunk parameters required a review of this site. The calibration period was kept as November 21-26, 2013, as this location indicated higher flows during the winter months and provided more conservative modeling results.

Compared to the original calibration, the upstream changes did not result in the need to adjust the defined DWF parameters for the tributary area downstream of FWL-22, as similar metrics for closeness-of-fit were achieved.

Table 5.3: Dry Weather Calibration/Validation Results

Parameter	Calibration Results			Validation#1 Results			Validation#2 Results		
	Observed	Simulated	Difference	Observed	Simulated	Difference	Observed	Simulated	Difference
FWL-4A (FM-002)	DWF Period: November 21-26, 2013			DWF Period: July 21-26, 2013			DWF Period: March 13-28, 2014		
Volume (m^3)	78,187	79,493	2%	49,457	78,568	59%	93,398	77,690	-17%
Max. Flow (m^3/s)	0.265	0.238	-10%	0.173	0.237	37%	0.295	0.230	-22%
FWL-22 (FM-014)	DWF Period: November 21-26, 2013			DWF Period: March 13-28, 2014			DWF Period: N/A[1]		
Volume (m^3)	19,289	24,336	26%	21,470	24,336	13%	N/A	N/A	N/A
Max. Flow (m^3/s)	0.083	0.064	-23%	0.079	0.064	-19%	N/A	N/A	N/A
FWL-50 (FM-015)	DWF Mar 13-18, 2014			DWF Period: November 21-26, 2013			DWF Period: N/A[1]		
Volume (m^3)	8,834	8,534	-3%	8,998	8,534	-5%	N/A	N/A	N/A
Max. Flow (m^3/s)	0.037	0.035	-6%	0.034	0.035	2%	N/A	N/A	N/A

Note 1: A second validation period was not available.

5.3 WET WEATHER RECALIBRATION AND VALIDATION

5.3.1 Selection of Suitable Rainfall Events

The wet weather flow events available for recalibration and validation varied for the three flow monitoring locations due to coverage times. Five wet weather events were considered during recalibration based on storms with a significant depth and the duration of available flow monitoring data (October 30, 2013, May 28, 2013, June 28, 2013, July 5, 2013 and September 20, 2013). The only WWF event that was common to all three recalibration sites was the October 30, 2013 event. Additional WWF events common to all three monitoring periods could not be selected as the primary duration when all three sites had flow monitors installed occurred over the winter months when the precipitation was impacted by freezing and snowmelt. The remaining WWF events considered were only within the monitoring period at FWL-4A and were used to validate updates made in the Upper Forwell Trunk. Table 5.4 summarizes the event characteristics for the identified storms.

Table 5.4: Wet Weather Recalibration/Validation Rainfall Events

Event ID	Start	End of Rain	Duration[1] (hrs)	Total Rain (mm)	Peak Intensity (mm/5min)	End of WWF Response[2]
WWF 1	10/31/2013 3:00	11/1/2013 5:30	26.5	39.4	1.8	11/2/2013 3:00
WWF 2	5/28/2013 4:00	5/29/2013 15:15	35.3	40.6	9.1	5/30/2013 18:00
WWF 3	6/27/2013 22:45	6/29/2013 8:45	34.0	27.2	3.3	6/29/2013 23:00
WWF 4	7/4/2013 5:30	7/6/2013 11:00	53.5	42.4	9.1	7/06/2013 04:00
WWF 5	9/20/2013 08:45	9/21/2013 12:45	28	89.9	13.7	9/23/2013 08:00

1. Duration based on rainfall event
2. End of observed wet weather response for longest monitored flow, based on hydrograph separation

Additional storms were available for 2014 that overlap with FWL-22 and FWL-50. Of these storms, many exhibited low rainfall intensities and there was limited wet weather response observed in the flow monitoring data. The storms of significant volume unfortunately occurred in winter and early spring, and were therefore excluded from recalibration due to the likelihood of influence by snowmelt.

5.3.2 Recalibration Overview

Similar to the original calibration, wet weather flow events were input into the model and the model was calibrated using the RTK method. The RTK parameters were adjusted within the catchment area for FWL-50. Based on the review of the monitors downstream of FWL-50, the RTK parameters at FWL-4A and FWL-22 remained representative of the wet weather responses. Table 5.5 presents the wet weather input parameters for the Forwell sewershed area, while the recalibration/validation results are presented in Table 5.6.

Table 5.5: Wet Weather R-T-K Parameters

Monitor	R1	T1	K1	R2	T2	K2	R3	T3	K3
FWL-4A (FM-002)	0.025	0.21	28	0.005	12	5	0.001	24	4
FWL-22 (FM-014)	0.025	0.21	28	0.005	12	5	0.001	24	4
FWL-50 (FM-015))	0.017	1	20	0.007	12	5	0.001	24	4

Table 5.6: Wet Weather Calibration/Validation Results

WWF Event	Peak Flow (m^3/s)			Volume (m^3)		
	Observed	Simulated	Difference	Observed	Simulated	Difference
FWL-4A (FM-002)						
May 28, 2013	0.257	0.484	88%	21,360	34,680	62%
Jun. 28, 2013	0.485	0.362	-26%	25,910	31,650	22%
Jul. 3, 2013	0.599	0.542	-9%	38,800	48,230	24%
Sep. 20, 2013	0.630	0.667	6%	58,470	58,440	0%
Oct. 30, 2013	0.3968	0.3167	-20%	64,540	47,230	-27%
FWL-22 (FM-014)						
Oct. 30, 2013	0.1077	0.08812	-18%	15,160	15,050	-1%
FWL-50 (FM-015)						
Oct. 30, 2013	0.049	0.045	-9%	6,452	5,570	-14%

Overall, the wet weather response at each of these three monitor locations is well replicated in the model. The FWL-50 catchment is a small residential area with a network of small diameter local sewers. It therefore exhibits different response characteristics than the downstream FWL-4A catchment area, which captures various land use types at the trunk sewer level.

The RTK parameters remained unchanged for catchment FWL-4A, and these parameters were found to be suitable for catchment area FWL-22. However, the recalibration efforts allowed for

the development of RTK parameters for the FWL-50 catchment, which exhibited different response characteristics than the downstream Forwell monitors (FWL-4A and FWL-22).

The following sections describe the specific findings of the wet weather recalibration with additional details in Appendix D.

5.3.2.1 Monitor FWL-50 (FM-015)

The catchment area upstream of monitor FWL-50 is a residential area with local small diameter sewers. Prior to recalibration, the RTK values applied in the FWL-50 catchment were identical to those developed for the downstream FWL-4A catchment area. This caused extreme surcharging when the design storm was applied, which was not representative of the responses seen in the flow monitoring.

During recalibration, a set of RTK parameters were developed for the FWL-50 catchment area which better suit the smaller local sewers in this residential catchment area. Based on a review of the flow monitoring data, it is determined that this area typically exhibits a lower magnitude response spanning a longer duration. Recalibration was able to capture these characteristics, and the model results for FWL-50 are within close proximity for the October 30, 2013 WWF event.

5.3.2.2 Monitor FWL-22 (FM-014)

Flow monitor FWL-22 receives flows from FWL-50, which is residential, and also collects flow from ICI properties including the St. Jacobs area. Model results for FWL-22 closely replicate the volumetric response for the October 30, 2013 WWF event. However, this monitor exhibits frequent fluctuations in flow, and therefore the peak flows are underestimated by the model. The RTK hydrograph parameters originally calibrated for the downstream FWL-4A were found to be suitable for this catchment area.

5.3.2.3 Monitor FWL-4A (FM-002)

The FWL-4A catchment area captures various residential neigbourhoods, and various ICI properties. This flow monitor receives flow from upstream monitors FWL-22 and LWD-6. The RTK parameters developed during original calibration were applied for the FWL-4A monitor, and the model results are within close proximity for the October 30, 2013 event.

Flow monitoring data was not available at locations FWL-22 and FWL-50 for the original four WWF events (September 20, 2013, June 28, 2013, July 5, 2013, and May 28, 2013); however, these events were used to validate the recalibration changes in the upstream FWL-50 catchment area.

The model simulation for the May 28, 2013 event significantly overestimates both peak flow and volume. The modeled and observed results were within a reasonable range for the June 28, July 5, and October 30, 2013 events, and were within very close proximity for the September 20, 2013 event. Therefore the WWF parameters for FWL-4A are considered acceptable.

6.0 SANITARY SYSTEM ASSESSMENT

The calibrated model is a tool that can be used to assess the baseline existing conditions. This section describes the methodology for evaluating the performance of the sanitary sewer system and provides an overview of modeling results for the calibrated current state conditions.

6.1 MODEL LIMITATIONS AND APPLICATION

The calibrated model is intended to represent the existing system performance as closely as possible given the available information and resources for the purpose of this study, as per the Terms of Reference. As noted in Sections 3.1.3 and 3.2.1, additional follow up is recommended to fine-tune model input parameters, including pump station operation and allocation of population data. In addition, there are inherent limitations with the application and use of any calibrated model, including the following:

- Given the size of the study area, it was not feasible to field survey all sewer assets and ground elevations. As-Recorded drawings were reviewed where available, but data inference based on engineering judgment was still required in many locations.
- Calibrated parameters were transposed to areas which did not have available flow monitoring data. These parameters were transcribed based on similar land use characteristics; however, additional flow monitoring would be required to confirm these assumptions. In other instances, only limited capture of suitable dry periods or rainfall events was available, not providing an ability to validate response.
- Given the complexity of surface, storm and sanitary sewer interaction both on the private and public side, extrapolation of observed low flow calibration parameters to extreme events must be interpreted with caution.

Notwithstanding the typical limitations above, the model development is within the normal application of large-scale planning studies and results should be interpreted according to this level of detail.

6.2 METHODOLOGY

To evaluate system performance, the criteria for capacity assessments must be defined. The following sections provide a summary of the level of service criteria and the design storms considered for the purposes of this study.

6.2.1 Level of Service Criteria

The target level of service is based on the capacity in the collection system and the risk of surcharging that would result in basement flooding. For DWF analysis, the ratio of maximum

depth versus full depth (d/D) shall be used to identify capacity constraints. The d/D ratio is more appropriate than the maximum flow versus full flow (q/Q) as it is more representative of system capacity for a dynamic model. In dynamic models, the slope of the hydraulic grade line can be greater than the pipe slope, thereby giving a false capacity error if only looking at flow ratio. Based on industry best practices, any sewers with a d/D equal to or greater than 0.8 (80%) shall be identified as having capacity constraints.

For WWF events, surcharging (d/D of greater than 1) is considered acceptable provided the water level remains at least 1.8 m below ground elevation. A water level of 1.8 m below ground elevation coincides with the assumed basement elevation for homes with direct or indirect basement connections to the sewer. An increase in water level beyond this would present a risk for basement flooding. Locations without house connections may further experience surcharge without risk of flooding, however these shall be identified case-by-case and be considered an exception. Figure 6.1 illustrates the targeted level-of-service for WWF events in relation to the water elevation and typical basement elevations.

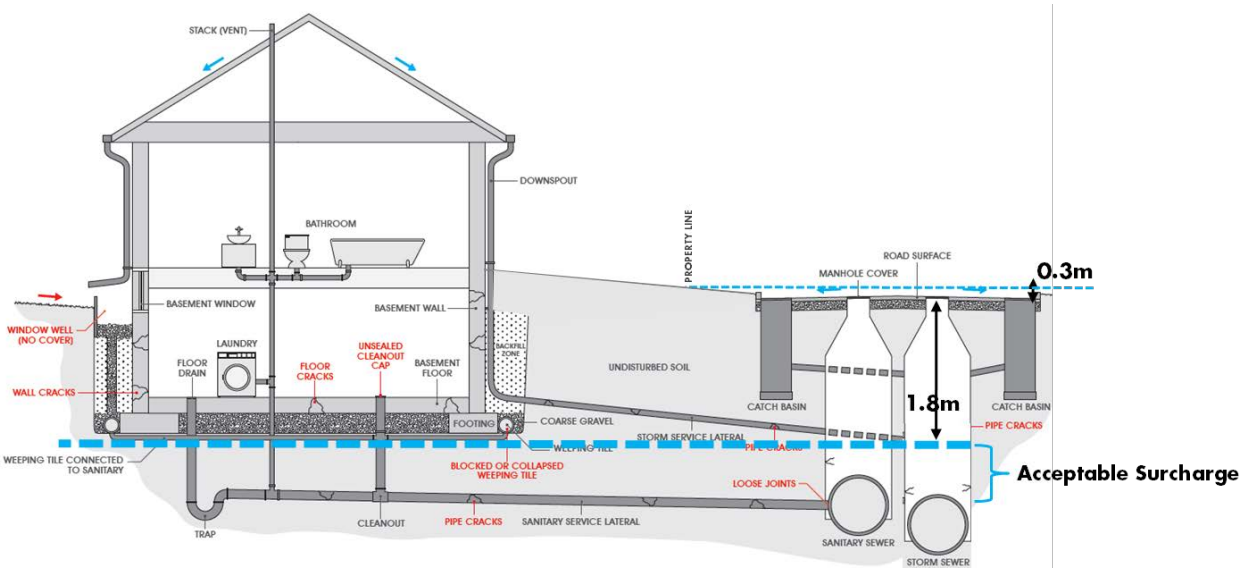


Figure 6.1: Definition of Flooding in Separated Sewer Systems

6.2.2 Design Storm Event

A standard design storm is not currently specified by the City for the purposes of sanitary system capacity assessment. Best practices based on the state of industry standards were reviewed, including what was used in the 2002 Master Plan. Design storms used by other organizations in Southern Ontario to evaluate the performance of sanitary systems include:

- 5-yr, 1 hour AES 30% Distribution (Region of Peel)
- May 12, 2000 Measured Historic Event (25- to 50-yr Return Period, City of Toronto)

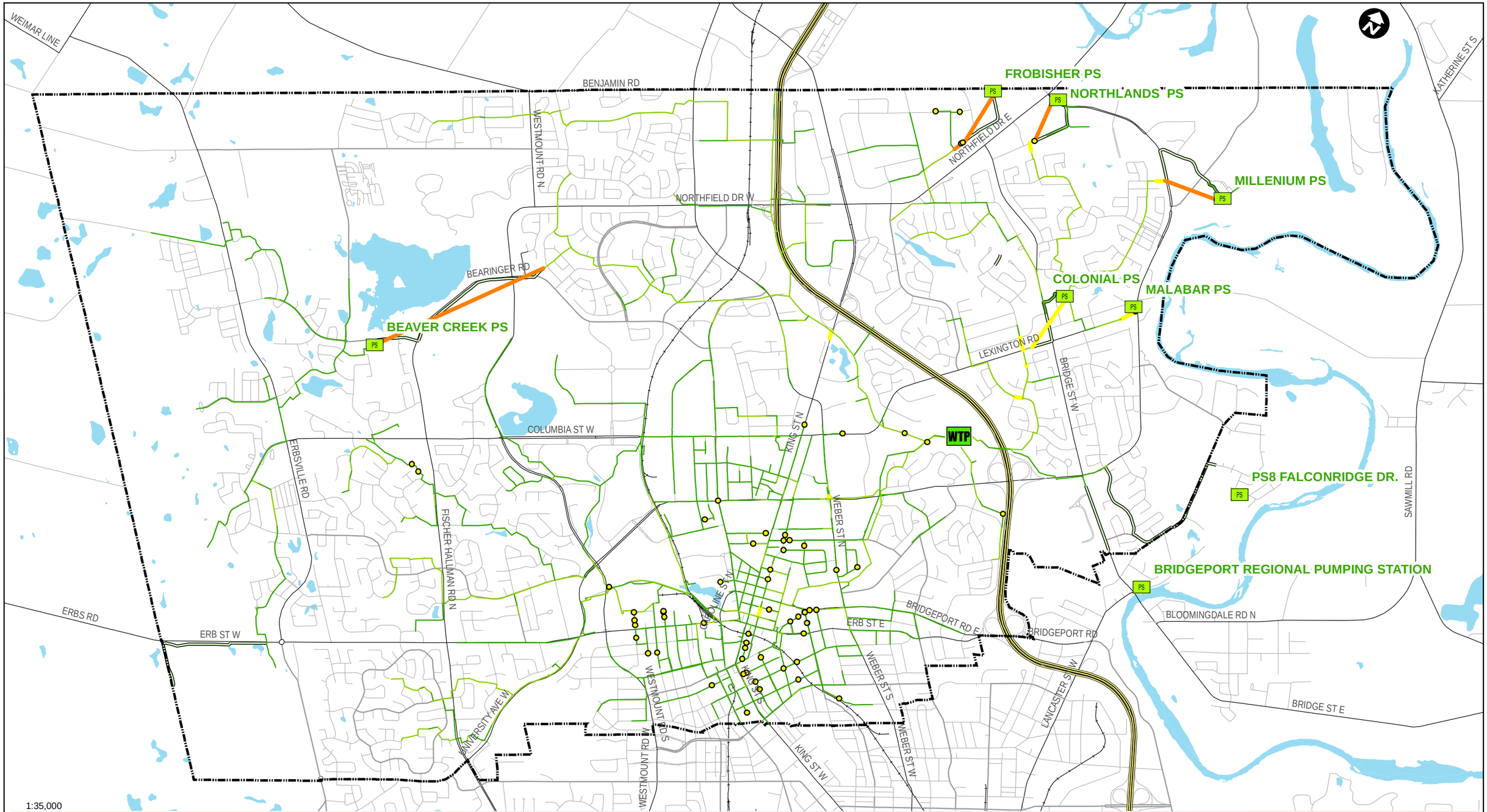
- 25-yr, 12 hour AES Distribution (City of Kitchener)
- 25-yr, 3 hour Chicago Distribution (City of Guelph)
- 5-, 10- and 25-yr, 3 hour Chicago Distribution (2002 Waterloo Master Plan)

The City of Toronto design storm is intended for flooding studies rather than sewer capacity review; therefore, it was not considered applicable for this study. The Region of Peel completed an extensive review and concluded that the 5-yr, 1 hour AES 30% Distribution was characteristic of storm events in Southern Ontario. Therefore, it was initially selected to review the capacity of the City's sanitary network. Modeling results, however, indicated the 5-yr, 1 hour AES 30% Distribution did not result in any capacity constraints. The 3 hour Chicago storm events were subsequently reviewed to provide more conservative results and allow a degree of comparison to the historic work completed for the 2002 Master Plan. In an effort to be conservative and acknowledge the trend of increasing intensity associated with climate change impacts, the 10-yr and 25-yr storms were selected for capacity assessments.

6.3 CURRENT STATE MODEL RESULTS

6.3.1 Dry Weather Modeling Results

Modeling results for the current state calibrated DWF model are presented in Figure 6.2. As indicated, the only concern for capacity occurs in a section immediately downstream of the Frobisher PS. Follow-up is recommended to confirm the pump curves at this station as the downstream constraint is related to the operating capacity of the pump being greater than the capacity of the sewers. The remainder of the system indicates the depth to diameter (d/D) ratio is below 0.8, which indicates the majority of the system is not under stress during dry weather. The depth to water, or hydraulic grade line freeboard, is also shown in Figure 6.2 to denote the degree of pipe surcharge relative to theoretical basement elevations. It can be noted that many nodes indicate a level that is within 1.8 m of ground elevation, however, the surrounding sewers are below their maximum capacity. This occurs because the sewer depth is shallow (within the 1.8 m freeboard allowance), thus any water level in the pipe will be within the threshold for surcharging even if the water level is low. In these situations, there is likely no basement connection or local property grading is elevated from the streetline, thus not a risk for flooding. Under DWF conditions, the section immediately downstream of Frobisher is the only section of manholes that indicate a level within 1.8 m of ground elevation related to surcharging. As noted previously, follow-up is recommended to confirm the pump curves for the Frobisher PS.



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- Highway
- Local
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Water Body

- PS Existing Pump Station
- Forcemain
- WTP Wastewater Treatment Plant

HGL Freeboard
- Above Ground
- Basement Depth (<1.8m)

d/D Ratio
- 0% - 20%
- 21% - 50%
- 51% - 80%
- 81% - 99%
- 100%

1611-11191

Figure No. FIGURE 6.2

Title DWF MODELING RESULTS FOR CALIBRATED CURRENT STATE CONDITIONS

Client/Project CITY OF WATERLOO SANITARY SERVICING MASTER PLAN UPDATE

6.3.2 Wet Weather Modeling Results

Both the 10- and 25-yr, 3 hour Chicago storm events were simulated for the current state model to evaluate the impact of extreme events on the system; an overview of the modeling results are presented in Figure 6.3 and Figure 6.4, respectively. The 10-yr, 3 hour Chicago storm event is the selected design storm event for the purposes of this study; however, the 25-yr, 3 hour Chicago event was reviewed as a stress-test on the system to denote any additional capacity issues that should be considered for capital planning.

Figure 6.3 indicates that under the 10-yr, 3 hour Chicago storm event, two areas of the collection system have a d/D of greater than 0.8, including downstream of the Frobisher PS, and a section of the Maple Hill Trunk. Review of the results indicates the water depths are within 1.8 m of ground elevation for each of these areas and therefore are a potential concern for flooding. The Frobisher PS has already been identified for follow up based on the DWF conditions, as there is uncertainty regarding the pump curves for this station. Surcharging in the section of Maple Hill Trunk occurs along the easement between Thorndale Dr. and Roosevelt Ave. Further investigation is recommended in this area to confirm if the surcharging represents a risk for basement flooding as the alignment is within an easement therefore potentially not having any house connections.

It is noted that Keats Trunk and Maple Hill Trunk were identified within the 2002 Master Plan as potentially having capacity constraints in future scenarios; however, the Keats Trunk does not indicate concern based on the current calibrated model. The connectivity of the landfill leachate pump discharge has been relocated from the Keats trunk to the Laurelwood/Beaver Creek system thereby reducing the load.

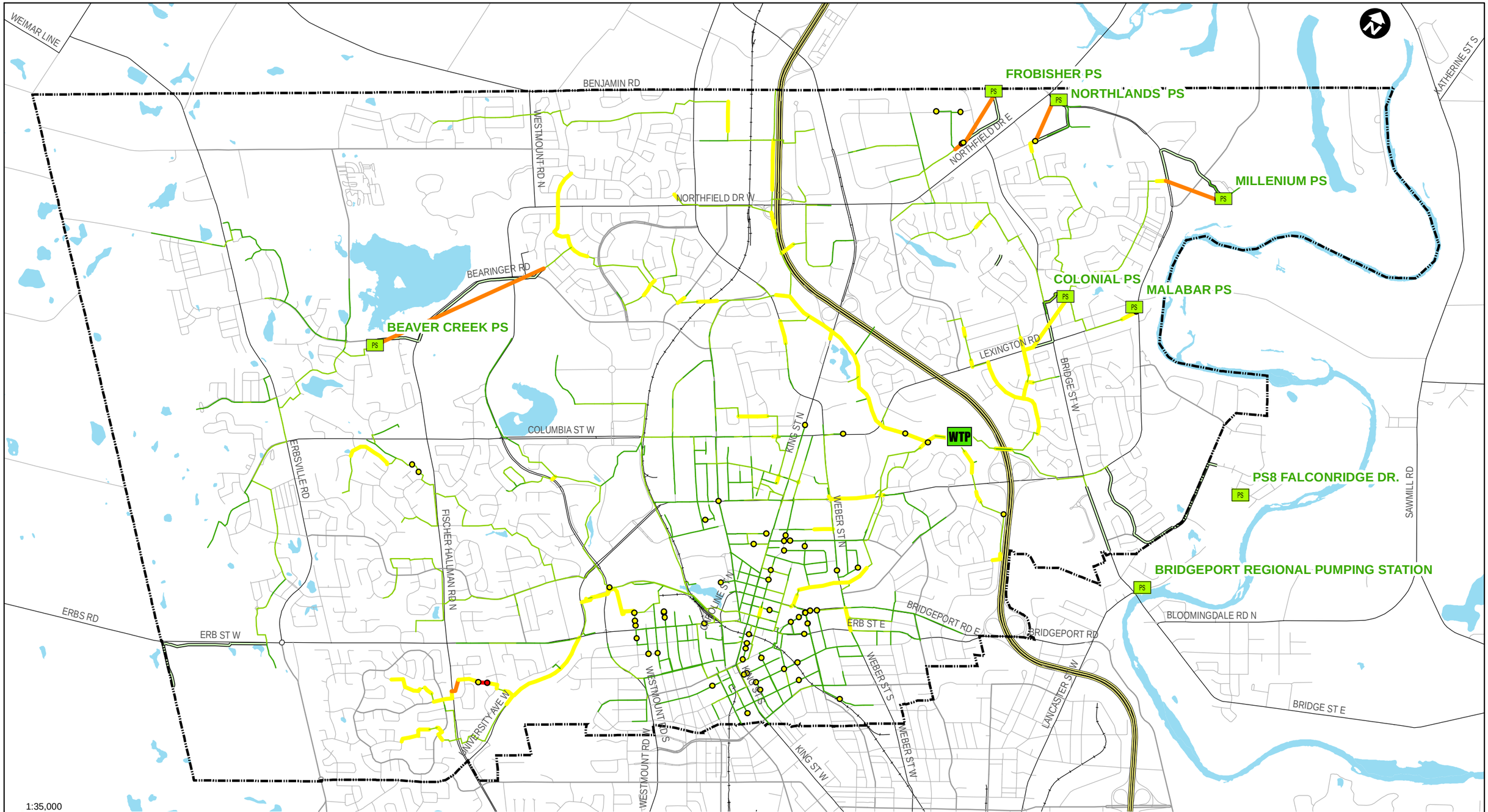
Figure 6.4 illustrates that under a 25-yr, 3 hour, Chicago storm event, the system is under more stress. Areas indicating surcharging within 1.8 m of ground elevation include:

- Downstream of Frobisher PS
- A section of Maple Hill Trunk
- The most upstream manhole in the subtrunk on Highpoint Ave., which ultimately discharges into the Cedar Trunk

The most upstream manhole in the subtrunk on Highpoint Ave. is the only location indicating high surcharging based on the increased wet weather flow beyond the 10-yr storm. Therefore under existing conditions, the system remains robust to the impacts of wet weather even considering the conservative 25-yr, 3-hr Chicago storm distribution.

One location within the Maple Trunk area (node 9249) shows surcharging above ground in the current state conditions under a 10-yr event. This node does not show surcharging in the 2013 Current State Model with the 25-yr storm, or any future scenarios. Further review of the model

results determined that the peak water level reported was the result of a computational instability that is not reflective of anticipated levels in the system. Based on flows, a more representative maximum depth at this location is 1.9 m, which is outside of the 1.8 m depth used to define a capacity constraint. Model instabilities are common in dynamic models of this size and complexity. Efforts to eliminate the instability through routing time-step reduction were reviewed; however, other physical network changes were not applied given the isolated nature of the spike, and the preference to maintain the modelled network as close as possible to the underlying GIS asset data.



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Legend

Transportation Network
- Arterial
- Collector
- Highway
- Local
- CityBoundary

Water Body

PS Existing Pump Station

Forcemain

WTP Wastewater Treatment Plant

HGL Freeboard
- Above Ground
- Basement Depth (<1.8 m)

d/D Ratio
- 0% - 20%
- 21% - 50%
- 51% - 80%
- 81% - 99%
- 100%

Figure No. FIGURE 6.3

Title WWF MODELING RESULTS FOR CALIBRATED CURRENT STATE CONDITIONS (10 YR, 3 HR, CHICAGO STORM)

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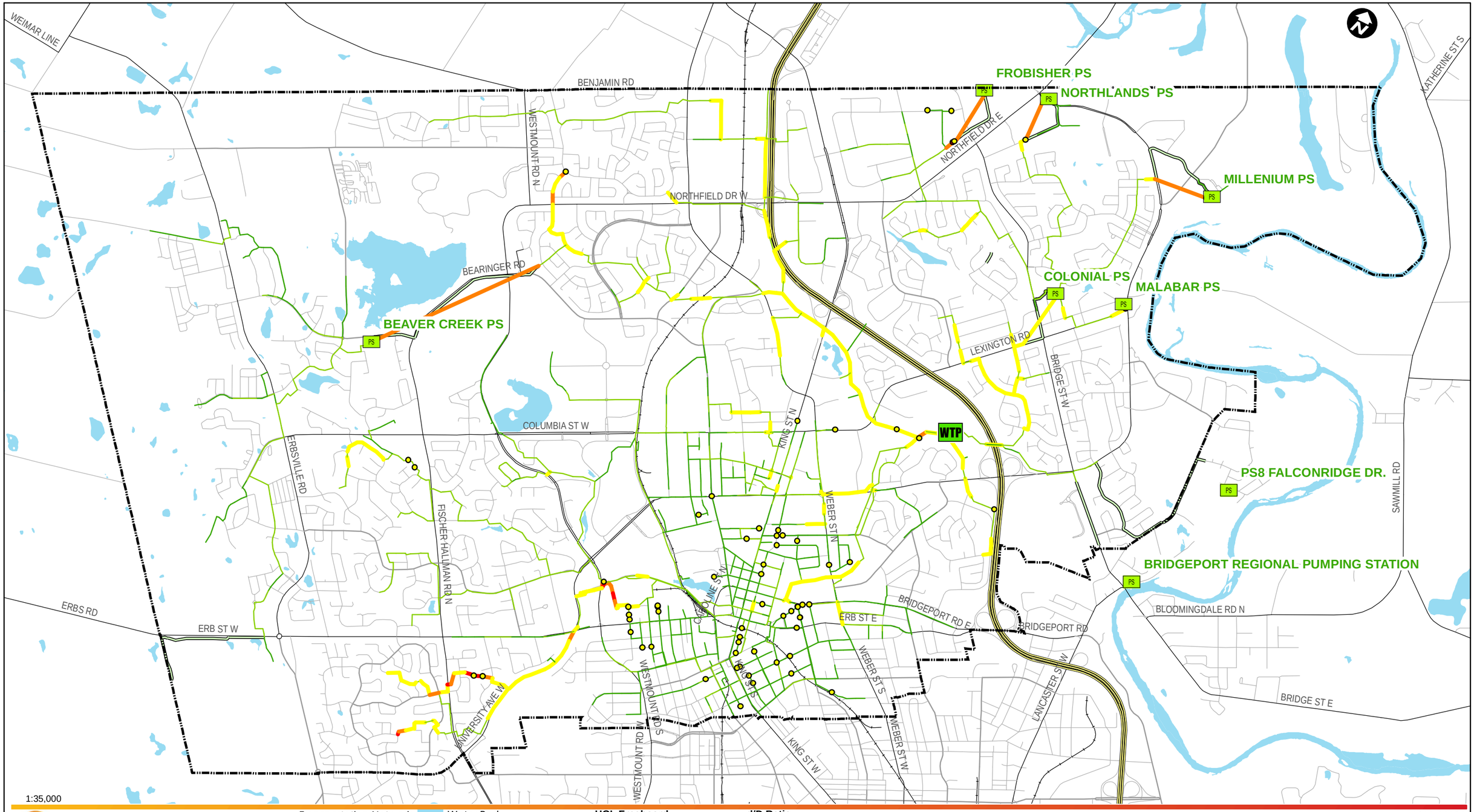

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Figure No. FIGURE 6.4

Title WWF MODELING RESULTS FOR CALIBRATED CURRENT STATE CONDITIONS (25-YR, 3-HR, CHICAGO STORM)

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7.0 FUTURE MODEL SCENARIOS

Scenarios have been set-up in the model to evaluate the ability of the collection system to accommodate future growth. Planned upgrades and estimated flow rates have been input into the future scenarios based on the information available at the time of the model development. These scenarios will be used as part of the Master Plan to recommend upgrades up to the planning horizon of 2029. At the time of model development, planning information had been provided up to a planning horizon on 2024. Model inputs have been established for 2014, 2019, and 2024 scenarios. Additional planning data has been provided and will be used to establish inputs for the 2029 model scenario. The model results and constraints arising from the 2029 model scenario will be discussed in Technical Memorandum #7, and will be used to identify and assess capacity constraints, and servicing alternatives.

7.1 FUTURE DRY WEATHER FLOWS

7.1.1 Future Population Data

The population growth values were provided within the *Development Charges Background Study* (Hemson Consulting Ltd., 2012). The spatial allocation of population growth was focused in two distinct areas: Greenfield development on the periphery of the City, and intensification in the Core Area. The growth in Greenfield areas was allocated based on the *City of Waterloo Staging of Development Report 2011-2014* (City of Waterloo, 2011), and intensification in the Core Area was allocated along the proposed LRT route.

7.1.1.1 Residential Population Growth

The Greenfield development was allocated to the developable land sites identified in *The City of Waterloo Staging of Development Report 2011-2014* (City of Waterloo, 2011). The report identified 39 developable lands sites and provided the anticipated type of dwellings and the projected of number units. Persons per unit (PPU) rates outlined in the District Plans (provided via email correspondence with the City, April 29, 2014) were used in conjunction with the information in the *Staging of Development Report* to calculate the future residential population. The PPU rates outlined in the District Plans were as follows:

- Single and semi-detached dwellings - 3.3 PPU
- Townhome dwellings - 2.48 PPU
- Apartments - 1.83 PPU

Population growth at each of these sites was allocated to each planning horizon (2014, 2019, and 2024). The *Staging of Development Report* was used as a basis for development timing, and site visits were completed to confirm the existing conditions. The development timing for the developable lands was assumed to be as follows:

- Already Constructed: Allocated in 2014
- Draft Approved, Priority Level 1, & Priority Level 2: Allocated in 2019
- Priority Level 5: Allocated in 2024

The difference between the City-wide residential population (based on the *Development Charges Background Study* (Hemson, 2012)) and the estimated population growth for Greenfield development was assumed to be intensification in the Core Area. The population growth in the Core Area was assumed to be concentrated along the proposed LRT route; therefore, the growth was allocated to address points along this corridor. In the 2014 and 2019 scenarios the LRT station area boundary was used to define the core infill area, and in the 2024 scenario a slightly larger boundary (the Study Area Boundary) was used to define the core infill area.

7.1.1.2 Student Population Growth

The growth in Off-Campus Student Population was based on the projections in the *Development Charges Background Study* (Hemson, 2012); however, no information was provided regarding the spatial allocation. As discussed in Section 3.2.1, similar challenges were encountered for the existing student population. For the purposes of this study, it was assumed that future student growth would be concentrated in areas already indicating high student populations. The Off-Campus Student growth was allocated to five DAs with the highest existing Off-Campus student populations (populations of greater than 990 students) (refer to Figure 3.3). The population increase within each DA was attributed using a similar approach, with population growth attributed to each parcel weighted by water consumption record.

On-campus student populations were assumed to remain constant throughout each of the planning horizons. It is difficult to estimate how this population will change, but it is expected that the off-campus student populations will grow much faster and will therefore have a greater impact.

7.1.1.3 Employment Population Growth

The City-wide projections were provided for employment population growth in the *Development Charges Background Study* (Hemson, 2012). The *Staging of Development Report* (City of Waterloo, 2011) identified some developable lands for ICI land use; however, the growth was not well categorized for the purposes of allocating population. To allocate population for the developing preliminary future scenarios, the preferred approach was to assume that 50% of the ICI growth be applied within the Core Area as part of the intensification, and 50% applied to the

remaining areas within the City. It is noted that the increases in ICI population were only applied to existing ICI properties.

7.1.1.4 Summary of Population Growth

A summary of the population growth is provided in Table 7.1.

Table 7.1: Future Populations for Planning Horizons 2014, 2019, and 2024

	2011	2014	2019	2024
Residential				
Total	98,681	103,647	112,484	122,076
Population Increase (over 2011)		4,966	13,803	23,395
Greenfield		2,058	7,141	13,324
Core Area (Station Boundary)		2,908	6,662	6,662
Core Area (Study Area Boundary)		-	-	3,408
Student (Off Campus)				
Total	16,944	17,570	18,620	19,670
Population Increase (over 2011)		626	1,676	2,726
DA 35300719 (30.1%)		188	504	821
DA 35300066 (26.1%)		163	437	711
DA 35300298 (14.4%)		90	241	393
DA 35300070 (12.2%)		76	204	333
DA 35300296 (17.2%)		108	288	469
Student (On Campus, Main Block)				
Total	4,828	4,828	4,828	4,828
Population Increase (over 2011)		-	-	-
Employment				
Total	63,473	63,661	72,720	79,429
Population Increase (over 2011)		188	9,247	15,956
Station Areas		94	4,624	7,978
Remaining ICI		94	4,624	7,978

7.1.2 Future Sewage Per Capita Rates

Future average sewage loading for residential growth was calculated using a design per capita rate of 350 L/c/d, as per the Design Guidelines and Supplemental Specifications for Municipal Services (DGSSMS). The DGSSMS and the Design Guideline for Sewage Works 2008 (Ministry of the Environment, 2008) states various design flows for industrial, commercial, and institutional lands on a per unit basis specific to the development type (i.e. area, number of beds, number of students, etc.). The level of detail provided for the planning data did not account for specific development properties and land uses, therefore, the residential design rate of 350 L/c/d was applied to all ICI property equivalent populations.

7.1.3 Future Baseline Flow (Groundwater Infiltration)

During the development of the future scenarios, an infiltration allowance of 0.15 L/s/ha was considered for future growth areas, as specified in the DGSSMS. This allowance was applied to the Greenfield development on the periphery of the City, but the Core Area infill was not attributed any increases in area, therefore, the design rate was not applied.

7.1.4 Future External Flows

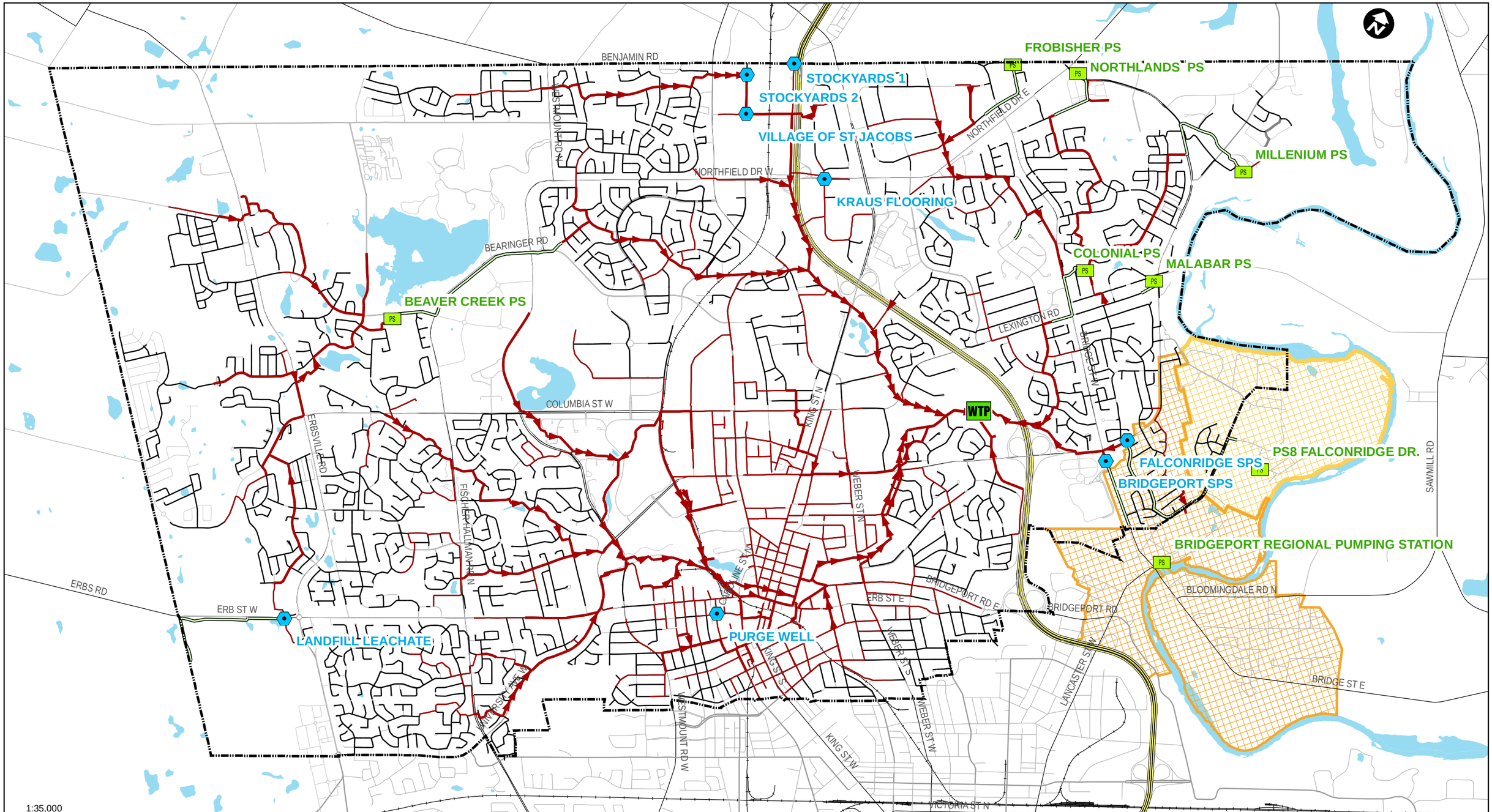
As noted in Section 3.2.4, the sanitary network receives flows from various sources outside the City's boundaries. Figure 7.1 illustrates the location of the external contributions and large users, which include the following sources:

- Leachate from the Waterloo Waste Management Site
- Inflows from the St. Jacob's Farmers Market and Stockyards area
- Inflows from the purge well (Well W14) and Kraus Flooring
- Inflows from Falconridge and Bridgeport PS (located in Kitchener)

Details regarding the future flow generated from these users are described in the following sections.

7.1.4.1 Waterloo Waste Management Site Leachate Flow

As discussed in Section 3.2.3.1, the Waterloo Waste Management Site collects and pumps leachate via PS-3 into the City of Waterloo's Sanitary Network along Ira Needles Blvd. The forcemain from PS-3 discharges to node CH25-18 (15530). Future plans exist to increase the discharge rate to a maximum rate of 15.2 L/s. The agreement between the Region and the City regarding the leachate discharge is currently being updated. The increase in flow is expected to come into effect in between 2017 and 2019; however, there is the potential for it to be implemented earlier. As a conservative measure, a maximum rate of 15.2 L/s has been applied for each of the planning horizons (2014, 2019, and 2024).



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Legend

- CityBoundary
- Water Body
- Forcemain
- PS — Existing Pump Station
- WTP — Wastewater Treatment Plant

All Sanitary Sewers
- Local Sewers
- Trunk Sewers

Model Selection Set
- Local Sewers
- Trunk Sewers

External Contributions and Large Users

Kitchener Drainage Areas
- Bridgeport Pump Station
- Falconridge Pump Station

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Figure No. FIGURE 7.1

Title EXTERNAL CONTRIBUTIONS AND LARGE USER FLOWS

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The volume of leachate is also expected to increase, as outlined in the Leachate Management Plan Update (Conestoga-Rovers & Associates (CRA), 2013). Table 7.2 outlines the estimated leachate volumes for future years based on the planned construction of additional cells within the south expansion area. The leachate production rates for each of the planning horizons (2014, 2019, and 2024) were interpolated from the future leachate generation rates provided in the Leachate Management Plan Update.

Table 7.2: Leachate Generation Rates for Planning Horizons

Leachate Generation at PS-3[1]		Leachate Generation Model Inputs for Future Scenarios[2]	
Timing	**Flow (m^3/d)**	**Model Scenario**	**Flow (m^3/d)**
Current (2012)	127.7	2014	146.4
Peak (2029)	286.8	2019	193.2
Post Closure	207.5	2024	240.0

Note 1: As reported in the Leachate Management Plan Update (CRA, 2013)
Note 2: Interpolated based on values from the Leachate Management Plan Update (CRA, 2013)

7.1.4.2 Stockyards Development

Information regarding the Stockyards Area was provided by the Township of Woolwich and determined based on flow monitoring data, as discussed in Section 3.2.4.2. The Township also provided some guidance regarding which properties had been developed and which properties were planned for development (refer to Appendix C). For a conservative estimate of future inflows, it was assumed that all properties within this area will be fully developed by 2019. The flows associated with each planning horizon are summarized in Table 7.3. The diurnal pattern developed from flow monitoring completed in 2011 and 2013 have been applied in future scenarios, as discussed in Section 3.2.4.2.

Table 7.3: Design Flows for Stockyards Area

Planning Horizon	Model Node	Peak Flow (L/s)	Average Flows (L/s)	Baseline Flow (L/s)
2014	MH 15639 (F38-4B)	6.0	2.9	1.2
	MH 11908 (F47-1)	4.6	2.3	2.8
2019	MH 15639 (F38-4B)	9.1	4.4	1.8
	MH 11908 (F47-1)	4.6	2.3	2.8
2024	MH 15639 (F38-4B)	9.1	4.4	1.8
	MH 11908 (F47-1)	4.6	2.3	2.8

7.1.4.3 Inflows from the Village of St. Jacobs

The St. Jacobs Wastewater Treatment Plant (WWTP) has been identified as experiencing high levels of I/I, which limits the capacity of the treatment plant through summer months. Rather than upgrade the St. Jacobs WWTP, the Region determined through the St. Jacobs – Elmira Wastewater Treatment Master Plan (XCG, 2013) that the St. Jacobs WWTP is to be decommissioned and the flows are to be diverted to the City of Waterloo's sanitary network for subsequent treatment at the Waterloo WWTP. The timing for diverting flows is uncertain at this time, however, it was assumed to take place within the next 10 years. As a result, the inflows from the Village of St. Jacobs are applied to the 2024 model scenario.

The projected flow to be received by the St. Jacob's WWTP in 2024 is 1,281 m^3/d (14.8 L/s) based on the 2013 Water and Wastewater Monitoring Report (Region of Waterloo, 2013). This flow was applied to model node 11904 (Manhole FWL-43).

It is expected that the existing St. Jacob's Wastewater Treatment Plant will provide flow equalization, allowing the flows to be discharged into the City of Waterloo network during off-peak hours. However, the pump station operating strategy has not yet been confirmed at this time. As a result, flows have been applied as a constant rate to allow a more conservative estimation of capacity.

7.1.4.4 Large User Flows

After calibration, it was noted that there are some users that discharge large flows to the collection system and may have a significant impact on localized capacity. Specifically, the purge well (Well W14) located in Uptown Waterloo and Kraus Flooring were identified as large users of concern. Although flows for these users were included in the calibration, they were not separated from the overall per capita rates applied throughout their respective sewershed. To evaluate the impact on the localized collection system, individual point loads have been added to the model for evaluating future conditions. Loadings for the large users were input into the model as summarized in Table 7.4. The same flow rates were used for all three future planning periods (2014, 2019, and 2024).

Table 7.4: Summary of Point Loads for Large Users

Large User	Model Node	Applied Flow (L/s)
Purge Well W14	12652	9.54
Kraus Flooring	12036	6.94

7.1.4.5 Bridgeport Pumping Station (Region of Waterloo)

As noted in Section 3.2.4.3, the catchment area for Bridgeport PS is split across the Kitchener-Waterloo Boundary. The growth in the catchments upstream of the Bridgeport PS is uncertain,

therefore, the firm capacity of the pump station was applied for all future scenarios to provide a conservative approach. The firm capacity of the pump station is 273 L/s, as per the Certificate of Approval (CofA).

7.1.4.6 Falconridge Pumping Station (City of Kitchener)

Peak flows were reported for the Falconridge PS within the *City-wide Sanitary Sewer System Capacity Study* completed by AECOM in 2011 for the City of Kitchener. The peak flow rates were applied, as shown in Table 7.5, as direct inflow to model node 15579 (Manhole LEX-15A).

Table 7.5: Falconridge PS Current and Future Capacity Estimates

Parameter	Peak Inflow - Current Scenario	Peak Inflow - 50% Growth	Peak Inflow - 100% Growth
Planning Horizon	2014	2019	2024
Peak Flow (L/s)	12.97	19.49	25.97

7.2 FUTURE WET WEATHER FLOWS

In the development of the future scenarios, all areas of future growth have been assigned a unit hydrograph defined by RTK parameters. The unit hydrograph assigned to each growth area is that which was developed for the specific area during WWF calibration. In the near-term, the impact of wet weather from new development should not be as excessive as the calibrated older areas, since private-side extraneous flow connections are illegal and not connected to the sanitary system, and new construction should exhibit good seals and structural integrity if proper inspection and installation practices are observed. Therefore, the application of the calibrated RTK parameters to new areas is considered conservative.

7.3 FUTURE SCENARIO MODEL RESULTS

7.3.1 Dry Weather Modeling Results

The dry weather flow scenarios have been assessed for the 2014, 2019, and 2024 planning periods. The results are displayed in Figure 7.2 to Figure 7.4 for the d/D ratio in the links and the minimum freeboard in the nodes.

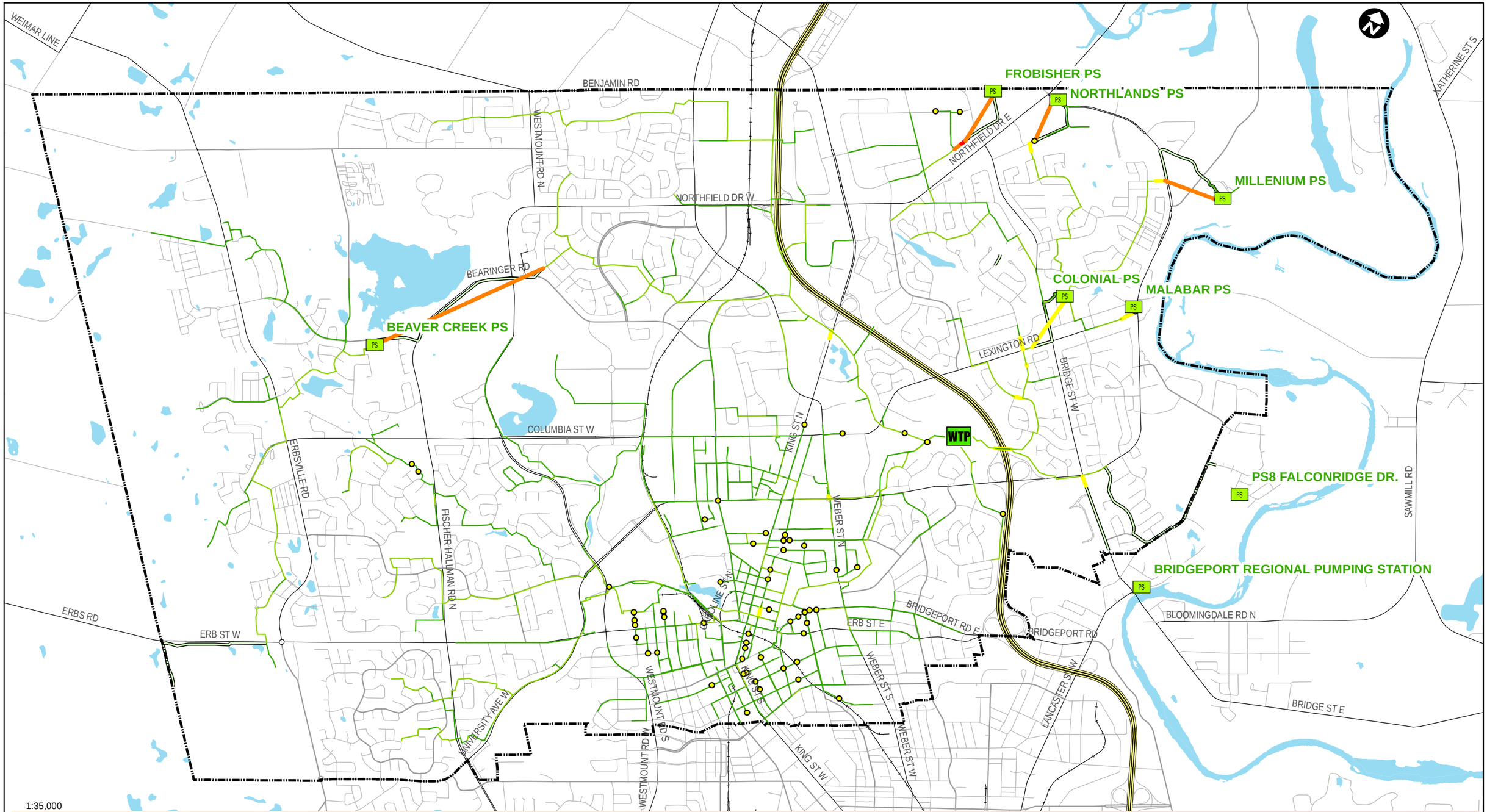
The constraint, identified in the current state model, downstream of Frobisher PS remains in the future scenarios. Follow-up is recommended to confirm the pump curves at the Frobisher PS (as noted in Section 6.3.1). It is also recommended that this area be monitored, and detailed capacity assessment should be completed if any development is considered in this area.

Aside from this location, no other sewers indicate capacity constraints under DWF conditions up to the 2024 planning horizon.

Although the receiving sewers downstream of Beaver Creek PS, aligned on the easement east of Dogwood Lane and along Fallingbrook Ave. are not showing significant surcharging in the model simulations, it should be noted that there may be potential concerns associated with the proposed capacity upgrades.

In the *Beaver Creek Capacity Assessment Report* (Gamsby and Mannerow, 2012), it was recommended that peak instantaneous flow rate of 439 L/s be utilized for ultimate build-out conditions for a planning horizon of 2022. Future upgrades to the pump station include the addition of a 500 mm forcemain which will twin the existing 350 mm forcemain, the total combined forcemain capacity is to be 440 L/s total flow.

In the DWF 2024 Model Scenario the pump station does not operate at the peak capacity of 439 L/s. Therefore a capacity assessment was completed for the Beaver Creek PS. It was determined that the Beaver Creek PS could operate at a maximum capacity of 400 L/s under the 2024 growth scenario without triggering upgrades to the receiving sewers. If the Beaver Creek PS operates at a capacity of greater than 400 L/s, then the d/D ratio of the receiving sewers will exceed 0.8 (80%), and upgrades would be required based on the level of service discussed in Section 6.2.1.



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Legend

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Water Body

PS Existing Pump Station

Forcemain

WTP Wastewater Treatment Plant

HGL Freeboard
- Above Ground
- Basement Depth (<1.8m)

d/D Ratio
- 0% - 20%
- 21% - 50%
- 51% - 80%
- 81% - 99%
- 100%

1611-11191

Figure No. FIGURE 7.2

Title DWF MODELING RESULTS FOR FUTURE 2014 CONDITIONS

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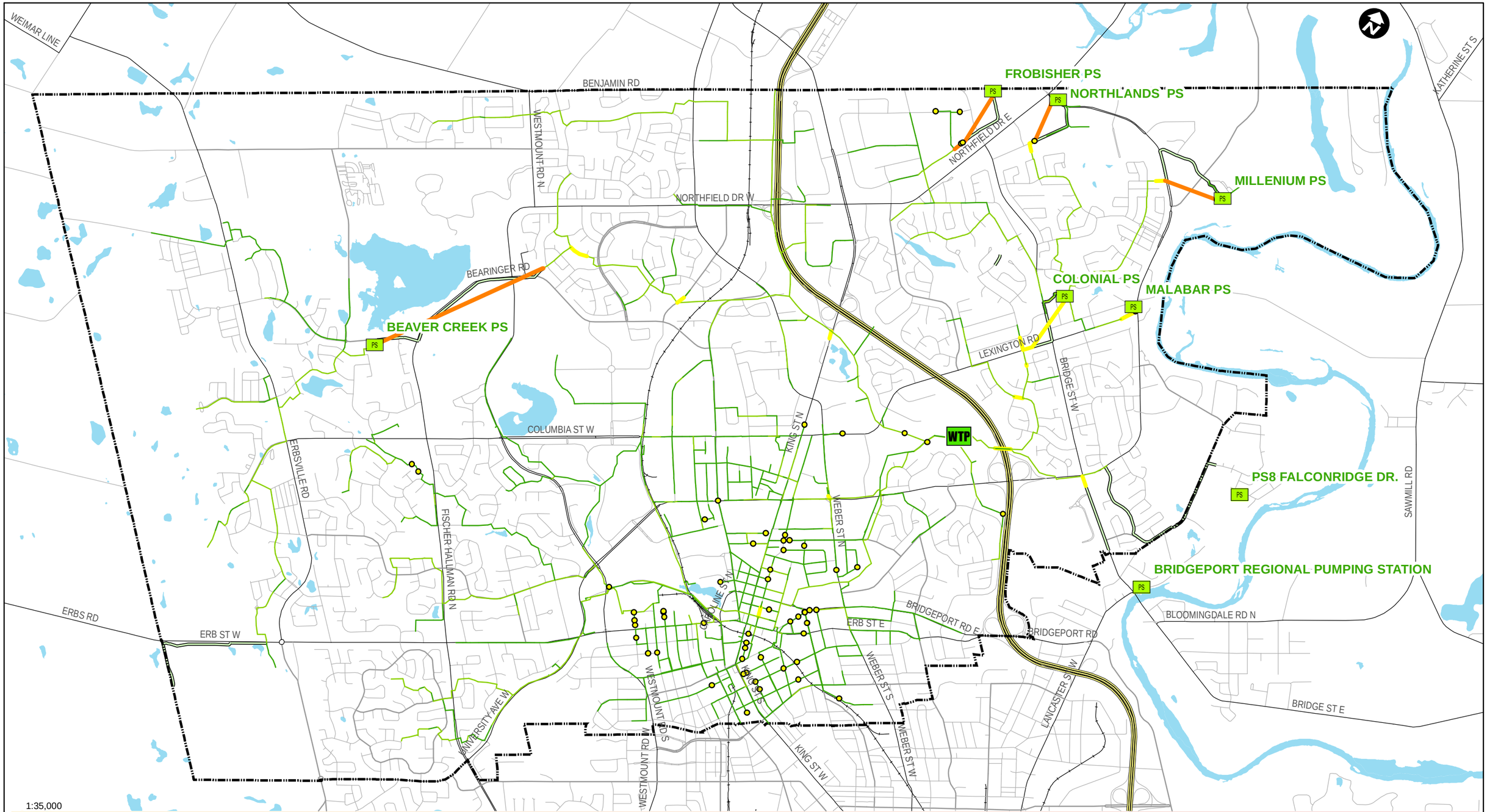

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- 100%

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Figure No. FIGURE 7.3

Title DWF MODELING RESULTS FOR FUTURE 2019 CONDITIONS

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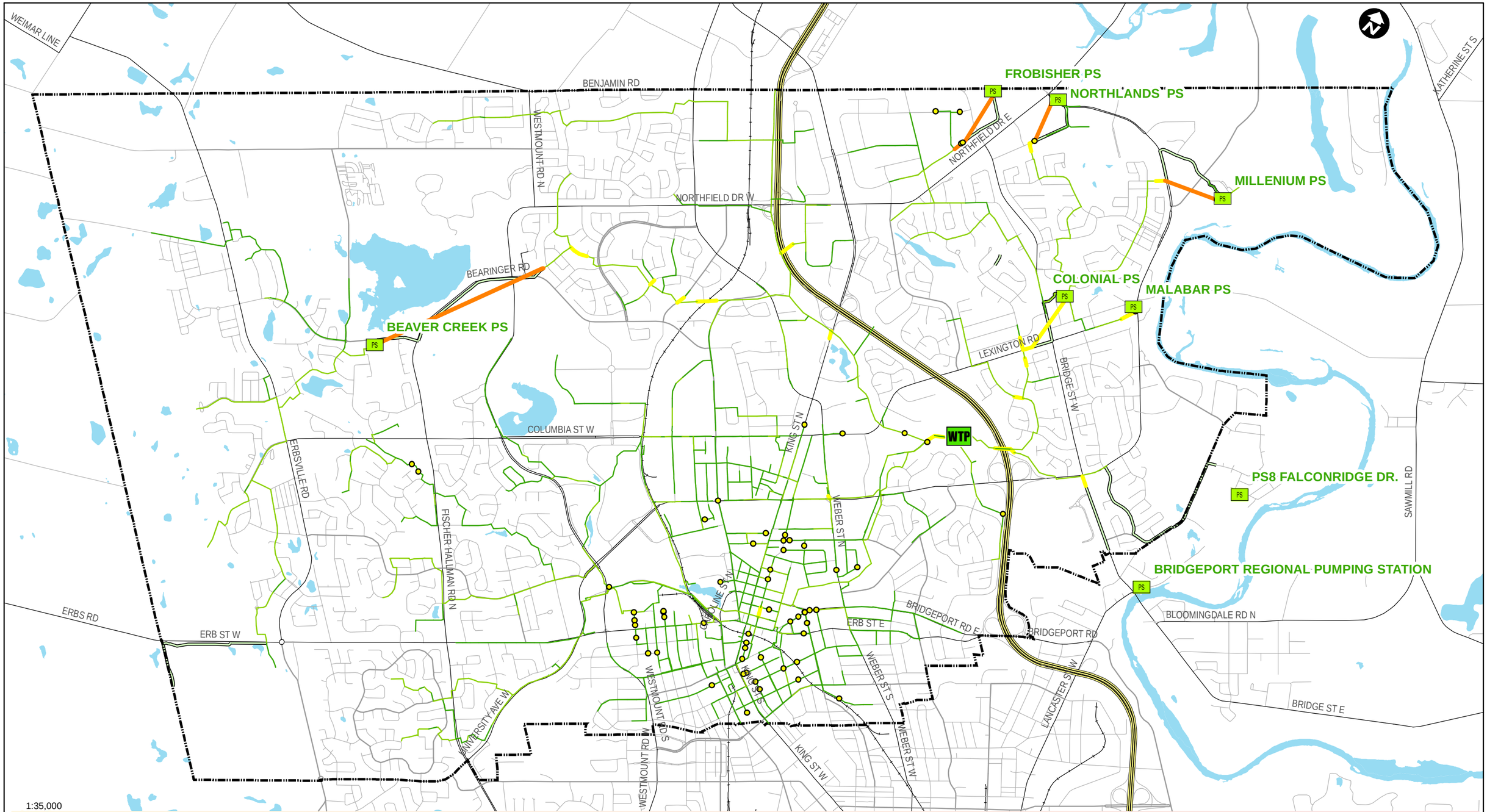

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- 100%

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Figure No. FIGURE 7.4

Title DWF MODELING RESULTS FOR FUTURE 2024 CONDITIONS

Client/Project CITY OF WATERLOO SANITARY SERVICING MASTER PLAN UPDATE

7.3.2 Wet Weather Modeling Results

The 10-yr, 3 hour Chicago storm event was reviewed for the 2014, 2019, and 2024 planning periods to evaluate the impact on the system. The results are displayed in Figure 7.5 to Figure 7.7 for the d/D ratio in the links and the minimum freeboard in the nodes.

The model indicates areas of surcharging as a result of sewers being at capacity:

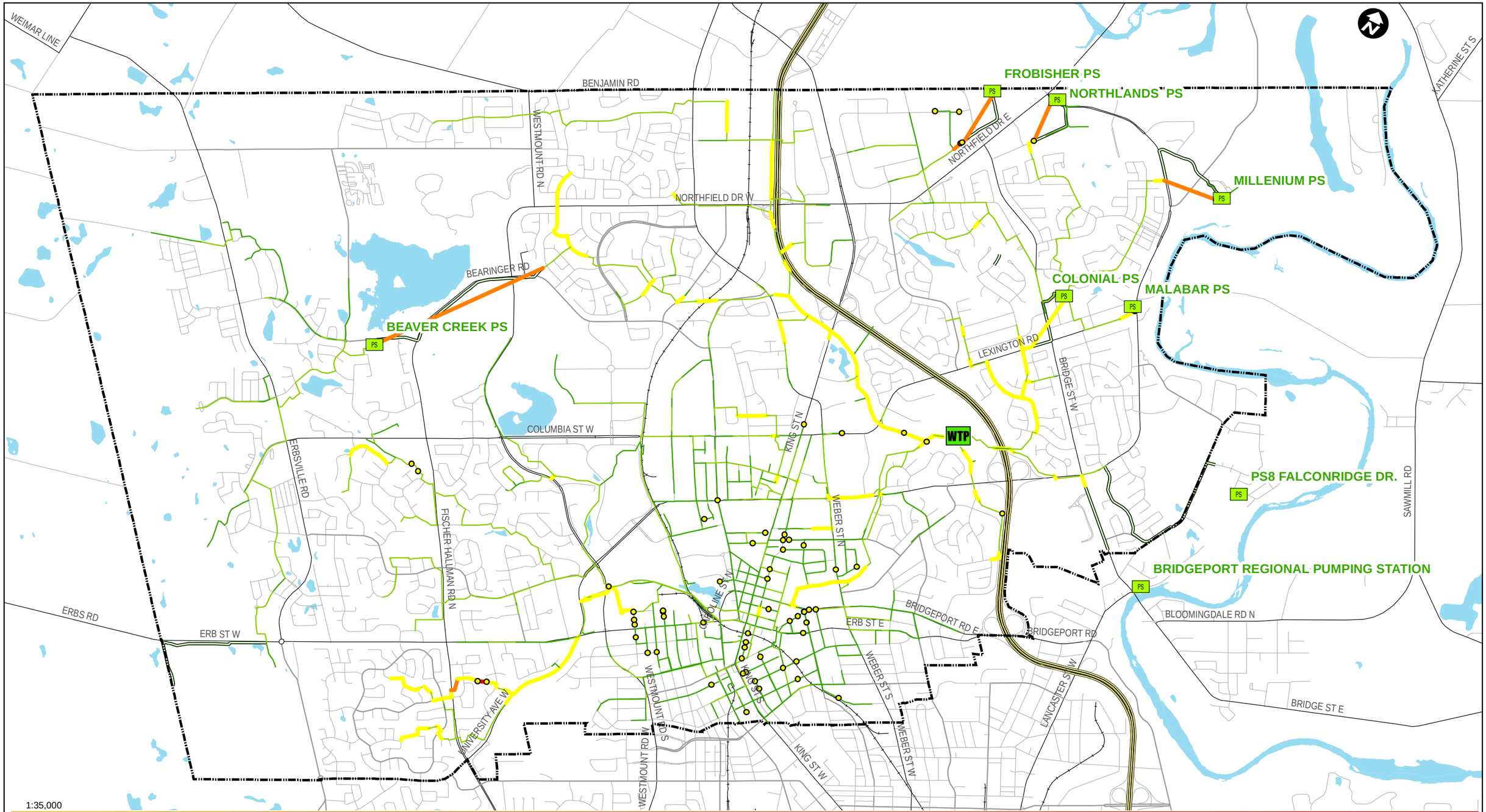
- Downstream of Frobisher PS
- A section of Maple Hill Trunk

Downstream of Frobisher PS and the section of the Maple Hill Trunk were previously identified as areas experiencing surcharging for the calibrated current state conditions.

Monitoring was recommended for the Frobisher PS to confirm results, as discussed in Section 7.3.1. In the case of the Maple Hill Trunk, surcharging occurs along an easement and follow-up is recommended to confirm the potential risk to basement flooding, as there may not be any connections along this section.

As discussed in Section 7.3.1, the Beaver Creek PS was reviewed to assess potential concerns associated with the proposed capacity upgrades. In the *Beaver Creek Capacity Assessment Report* (Gamsby and Mannerow, 2012), a peak instantaneous flow rate of 439 L/s was recommended for ultimate build-out conditions for a planning horizon of 2022. In the 2024 Model Scenario, with the 10-yr Chicago design storm applied, the pump station does not operate at the peak capacity of 439 L/s.

A capacity assessment was completed using the 2024 model scenario. It was determined that the Beaver Creek PS could operate at a maximum capacity of 440 L/s under the 2024 growth scenario without triggering upgrades to the receiving sewers based on the level of service for WWF discussed in Section 6.2.1. However, if the Beaver Creek PS operates at a capacity of greater than 400 L/s, then upgrades would be triggered under dry weather flow conditions because the d/D ratio of the receiving sewers will exceed 0.8 (80%), as discussed in Section 7.3.1.



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- 81% - 99%
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Figure No. FIGURE 7.5

Title WWF MODELING RESULTS FOR FUTURE 2014 CONDITIONS (10 YR, 3 HR, CHICAGO STORM)

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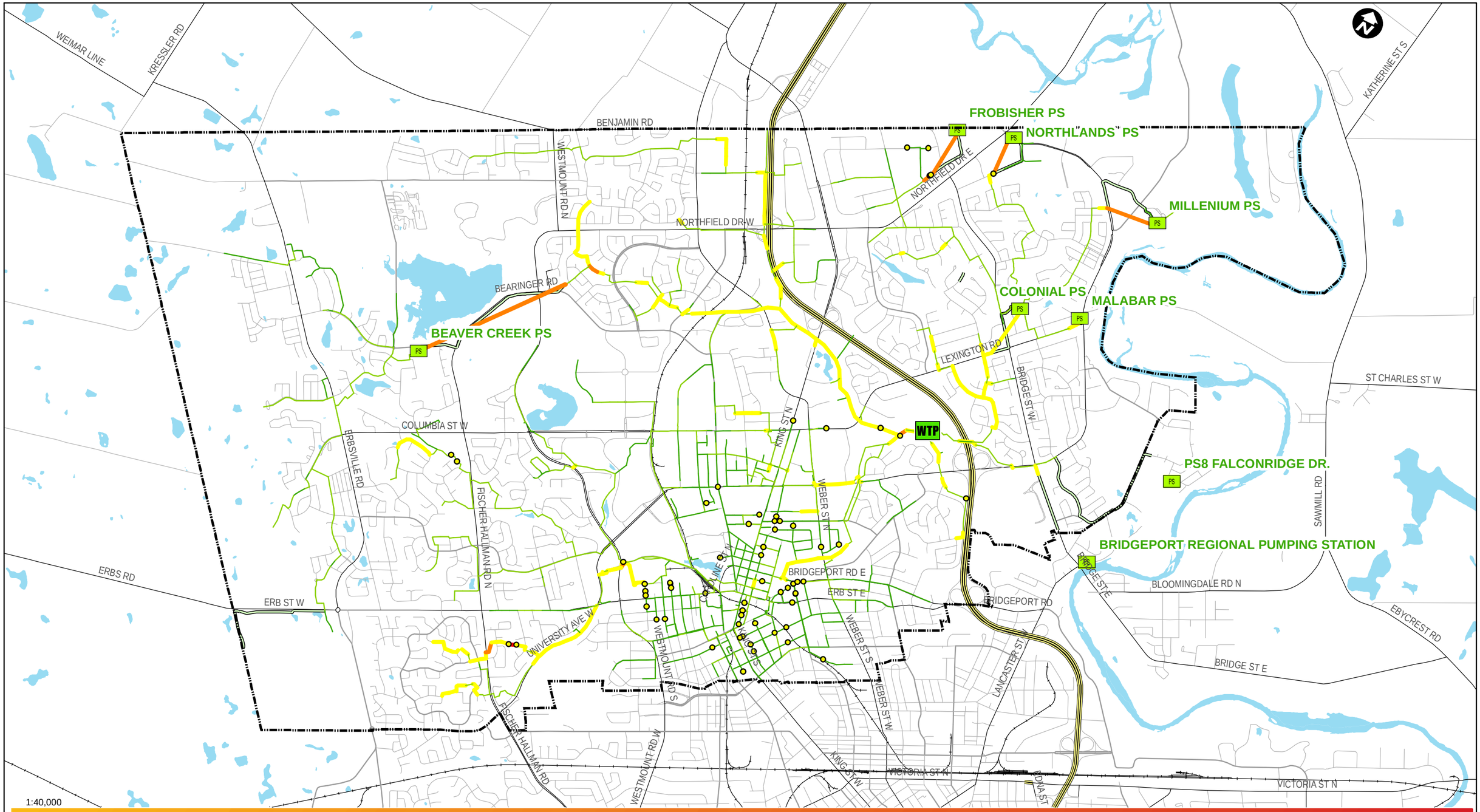

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d/D Ratio
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- 51% - 80%
- 81% - 99%
- 100%

Figure No. FIGURE 7.6

Title WWF MODELING RESULTS FOR FUTURE 2019 CONDITIONS (10 YR, 3 HR, CHICAGO STORM)

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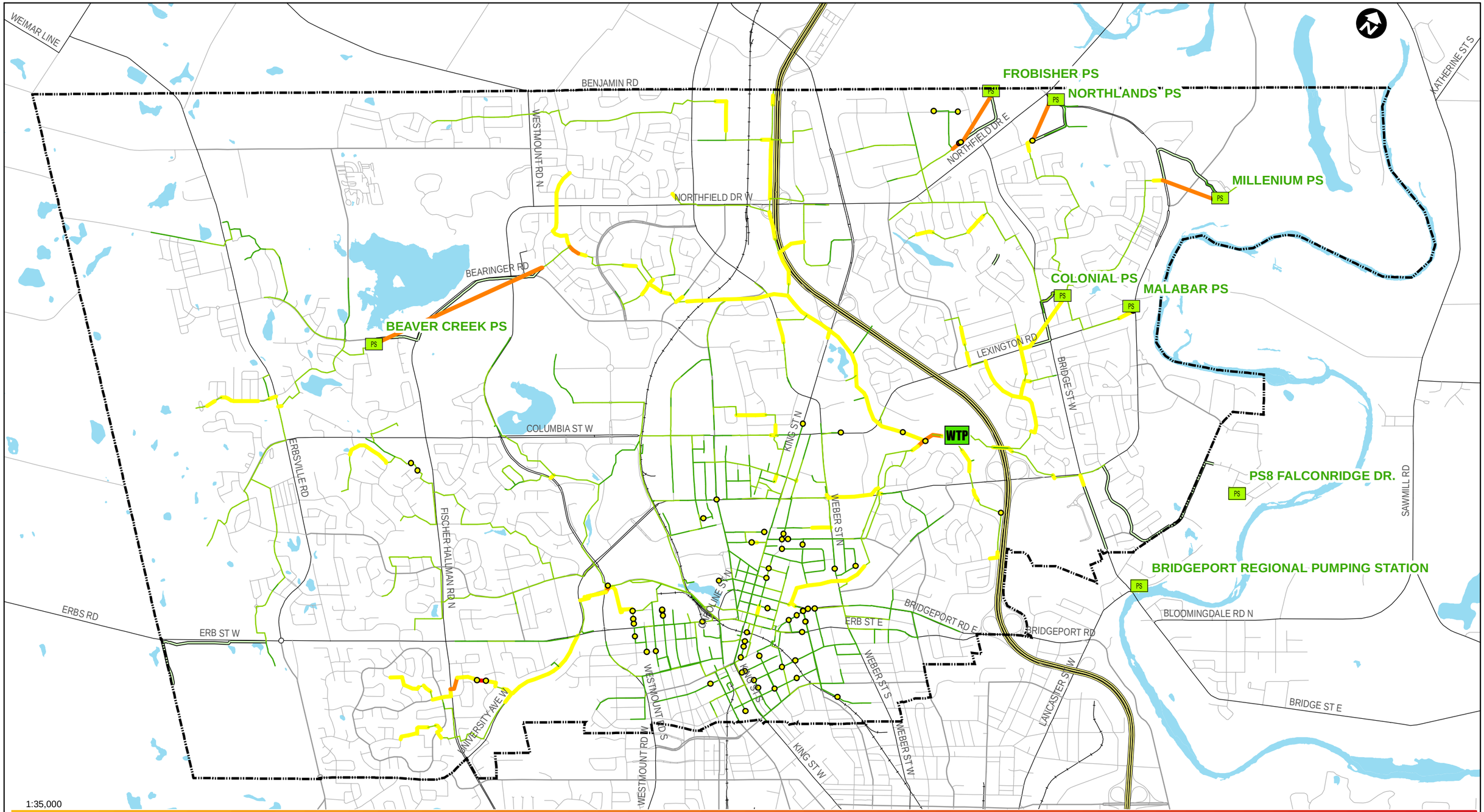

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Legend

Transportation Network
- Arterial
- Collector
- Highway
- Local
- CityBoundary

Water Body

- PS Existing Pump Station
- Forcemain
- WTP Wastewater Treatment Plant

HGL Freeboard
- Above Ground
- Basement Depth (<1.8m)

d/D Ratio
- 0% - 20%
- 21% - 50%
- 51% - 80%
- 81% - 99%
- 100%

1611-11191

Figure No. FIGURE 7.7

Title WWF MODELING RESULTS FOR FUTURE 2024 CONDITIONS (10 YR, 3 HR, CHICAGO STORM)

Client/Project CITY OF WATERLOO SANITARY SERVICING MASTER PLAN UPDATE

7.4 ON-GOING CALIBRATION

On-going calibration is recommended by the City to ensure the model is up-to-date for potential future uses. Updates are continuously being made to the physical infrastructure geodatabases and should be reviewed and incorporated into the model as appropriate. In addition, dry weather flow and wet weather flows should be reviewed and the loading data adjusted as necessary based on future flow monitoring data. As part of the City's flow monitoring efforts, locations could be strategically selected to focus on areas of interest to ensure the model is accurate for more localized areas.

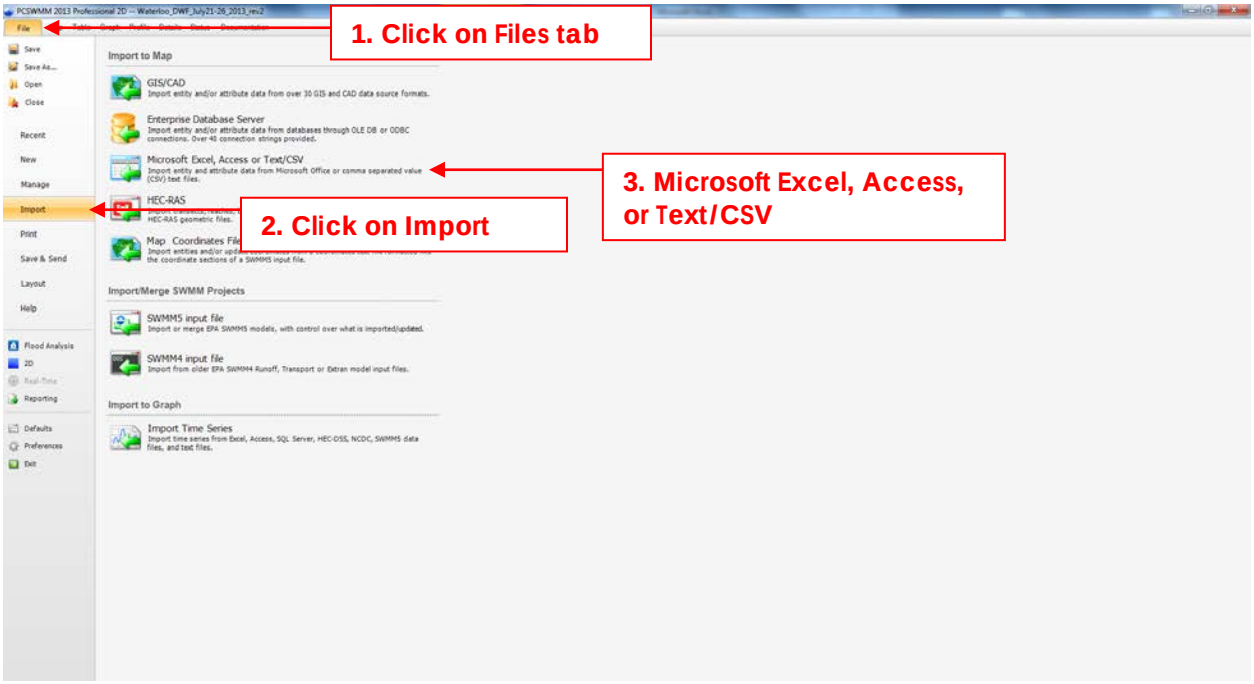
As the City progresses towards a full-pipe model, population and flow allocations will need to be updated. In a sub-trunk/trunk level model, upstream populations and flow rates are combined and applied at the most upstream manhole represented in the model. If additional infrastructure is being added upstream, the grouping of loading data will need to be updated to ensure flows are not applied multiple times.

7.5 PROCESS FOR UPDATING MODEL

7.5.1 Loading Data

Datasets can be loaded into the model as part of the development stage or to update an existing dataset. Steps to import data from a spreadsheet are provided below. Note that the same steps can be used to import a shapefile with minor modifications based on the selected file types:

1. Select the File tab.
2. Click on Import on the right hand menu list.
3. Select 'Microsoft Excel, Access or Text/CSV' (or select GIS/CAD to import a shapefile).



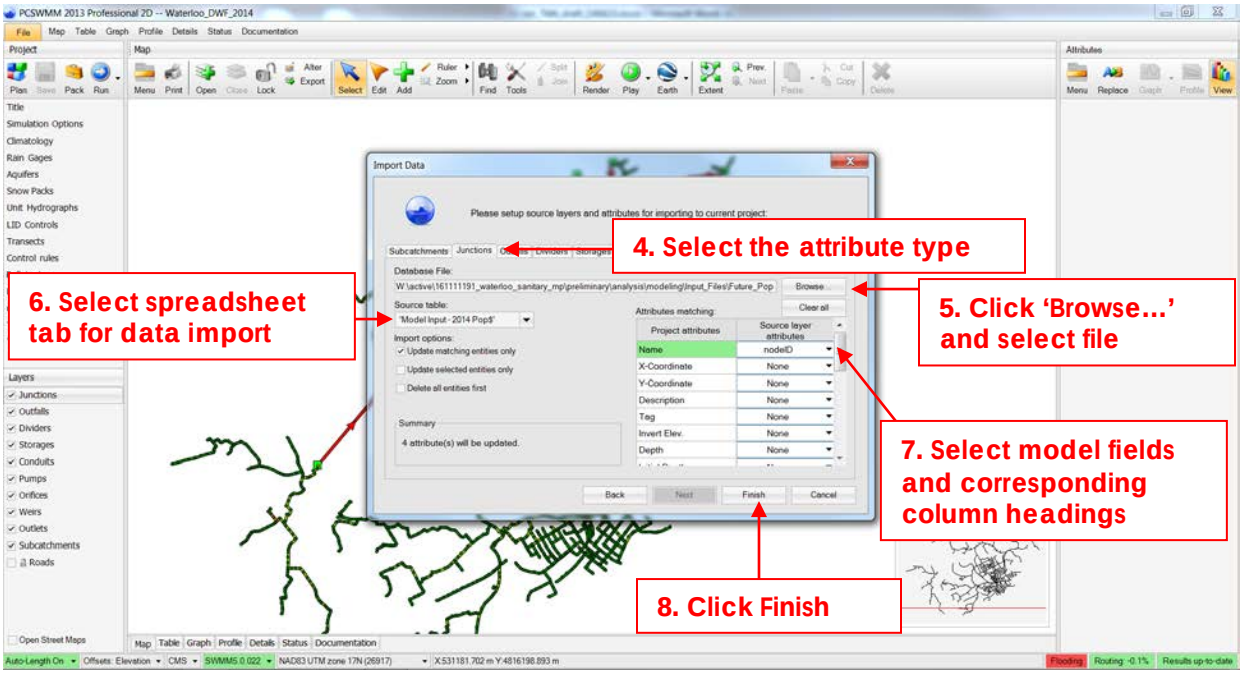
4. Under the Data Import dialogue box, select the attribute type to be updated.

5. Click on 'Browse…' and select the file to import.

6. Select the spreadsheet tab to be imported under the 'Source table:' drop-down menu.

7. Select the model fields to be updated and indicate the corresponding column headings from Excel under 'Attribute matching:'.

8. Click Finish.

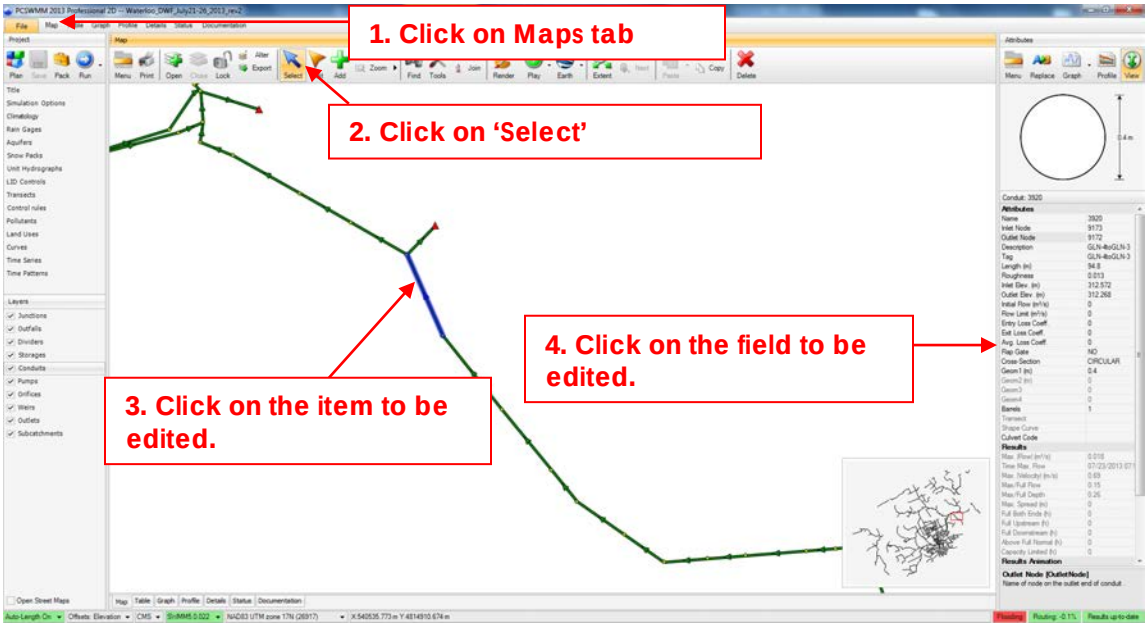

4. Select the attribute type
6. Select spreadsheet tab for data import
5. Click 'Browse…' and select file
7. Select model fields and corresponding column headings
8. Click Finish

7.5.2 Editing Attributes

Data can be edited in PCSWMM directly within the model or through importing external data sources (i.e. spreadsheets, shapefiles, etc.). Section 7.5.1 can be referred to for details regarding data imports. This section provides an overview of editing attributes directly within the model. When editing elements directly within the model, you can update data through the Attributes browser or through the Tables.

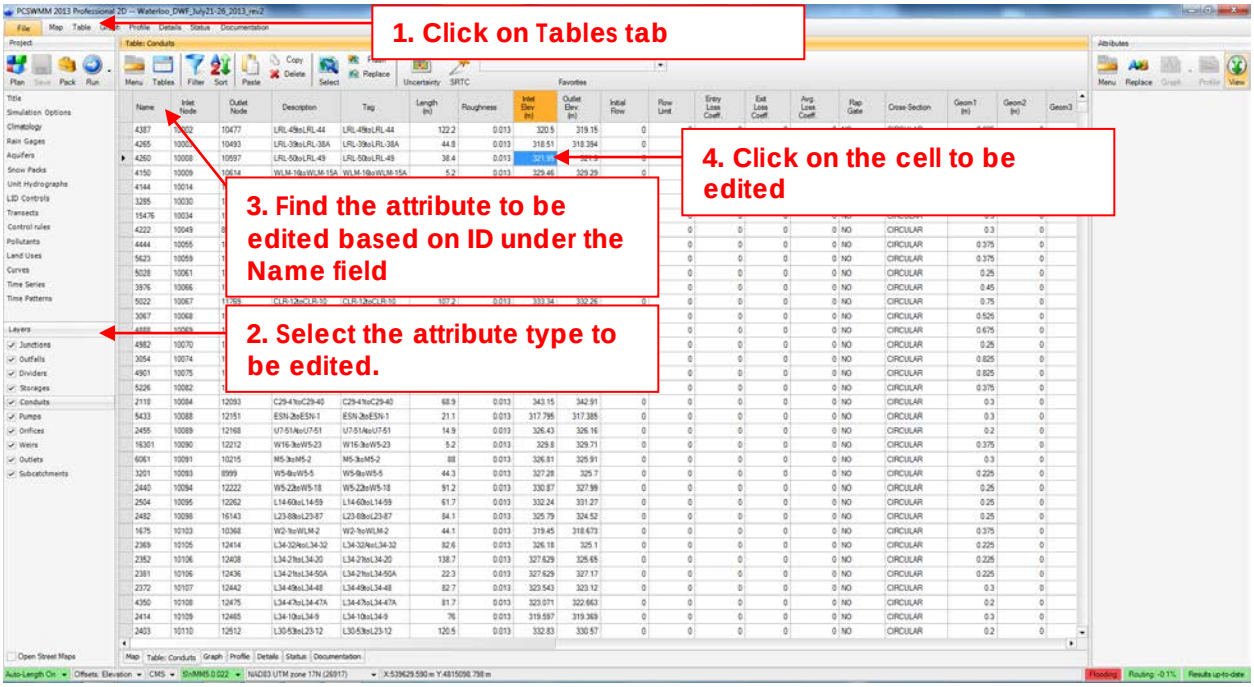
Steps to update data through the Attributes browser are provided below:

1. Click on the Maps tab on the top menu.
2. Click on the 'Select' mode in the Map Toolbar.
3. Click on the item you wish to edit (i.e. a specific junction, conduit, pump, wetwell, etc.).
4. Click on the field to be edited in the Attributes browser.



Steps to update data through the Tables are provided below:

1. Click on the Tables tab on the top menu.
2. Select the attribute type to be edited under the 'Layers' options.
3. Find the attribute to be edited based on the ID under the 'Name' column.
4. Click on the cell to be edited based on the column headings.

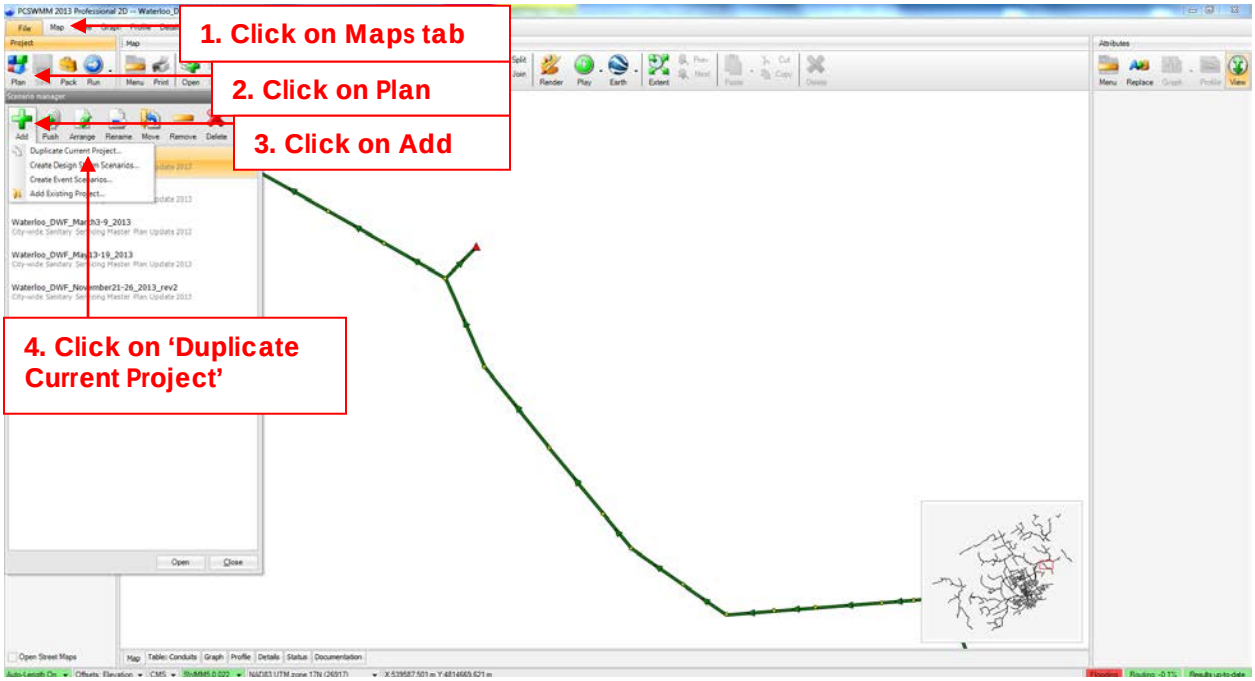

1. Click on Tables tab
4. Click on the cell to be edited
3. Find the attribute to be edited based on ID under the Name field
2. Select the attribute type to be edited.

7.5.3 Scenario Management

PCSWMM's scenario management is unique because, unlike other modelling software, the scenarios do not have a parent child relationship. This means that each scenario is a separate model and the parameters are not shared between models. As a result, changes made to one scenario are not carried through to the other scenarios.

Steps to create a new scenario based on an existing model are provided below:

1. Click the Maps tab.
2. Click on Plan.
3. Click on Add.
4. Click on 'Duplicate Current Project'.

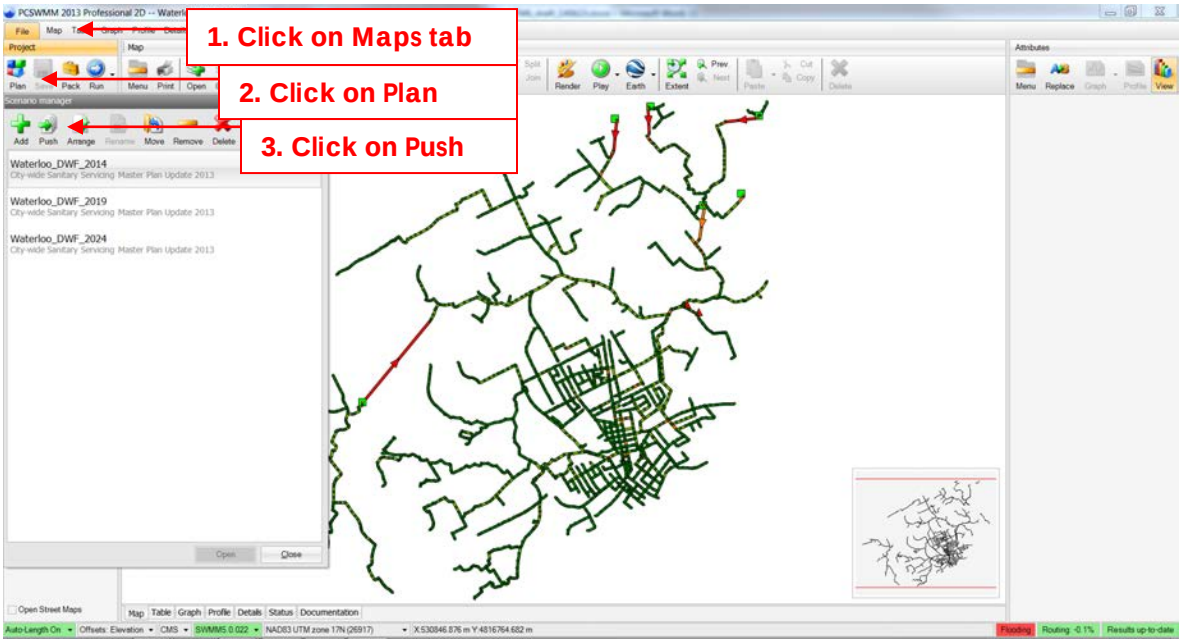


PCSWMM allows you to 'push' edits between scenarios. This allows you to make a change in one scenario and easily update multiple other scenarios without having to update each file individually. The steps for 'pushing' updates from one scenario to another are provided below:

1. Click the Maps tab.

2. Click on Plan.

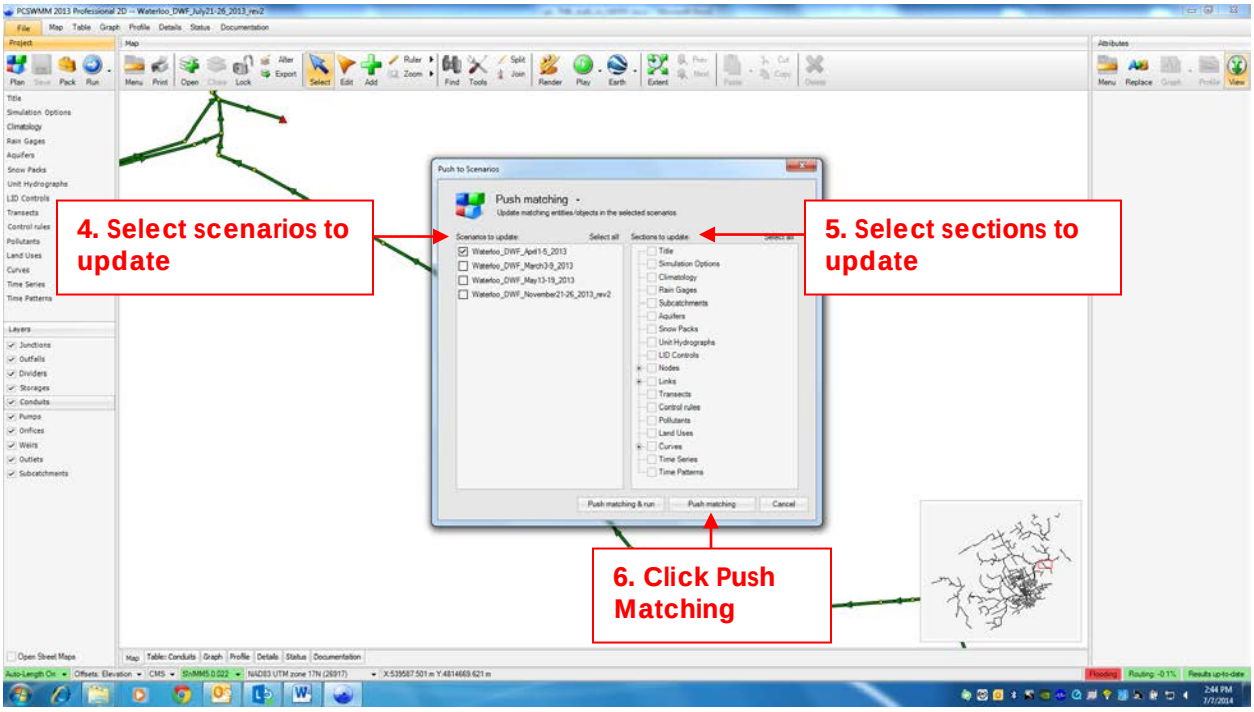
3. Click on Push.



4. Under the 'Push to Scenarios' dialogue box, select scenarios to update under the 'Scenarios to update:' heading. Note: If the scenario to be updated is not included in the list, add the scenario using the same Steps 1 through 3 to create a new scenario and then click 'Add Existing Project'.

5. Select elements to be updated under the 'Sections to update:' heading.

6. Click 'Push Matching'.



7.5.4 Interpreting Results

7.5.4.1 Viewing Results in Tabular Form

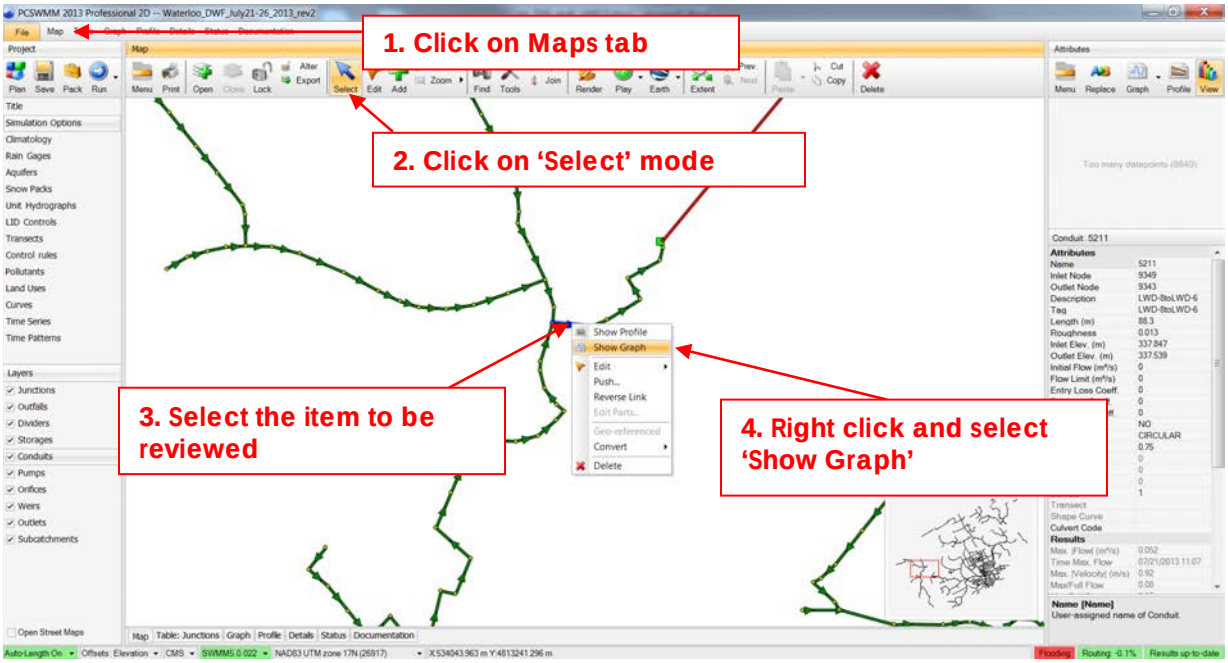
The inputs and model results may be viewed in tabular form using the Tables tab on the top menu. Under Layers on the right hand menu, the element to be viewed can be selected, including junctions, conduits, storages, and pumps.

7.5.4.2 Viewing Results in Graphical Form

The inputs and model results may be viewed in graph form using the Graph tab on the top menu. An element may be selected for review through the Map Window or the Graph Window.

The steps to view the graphical results for an element based on the Map Window are provided below:

1. Click on the Maps tab.
2. Click on the 'Select' mode in the Map Toolbar.
3. Select the specific item for which you would like to review results.
4. Right click and select 'Show Graph'.



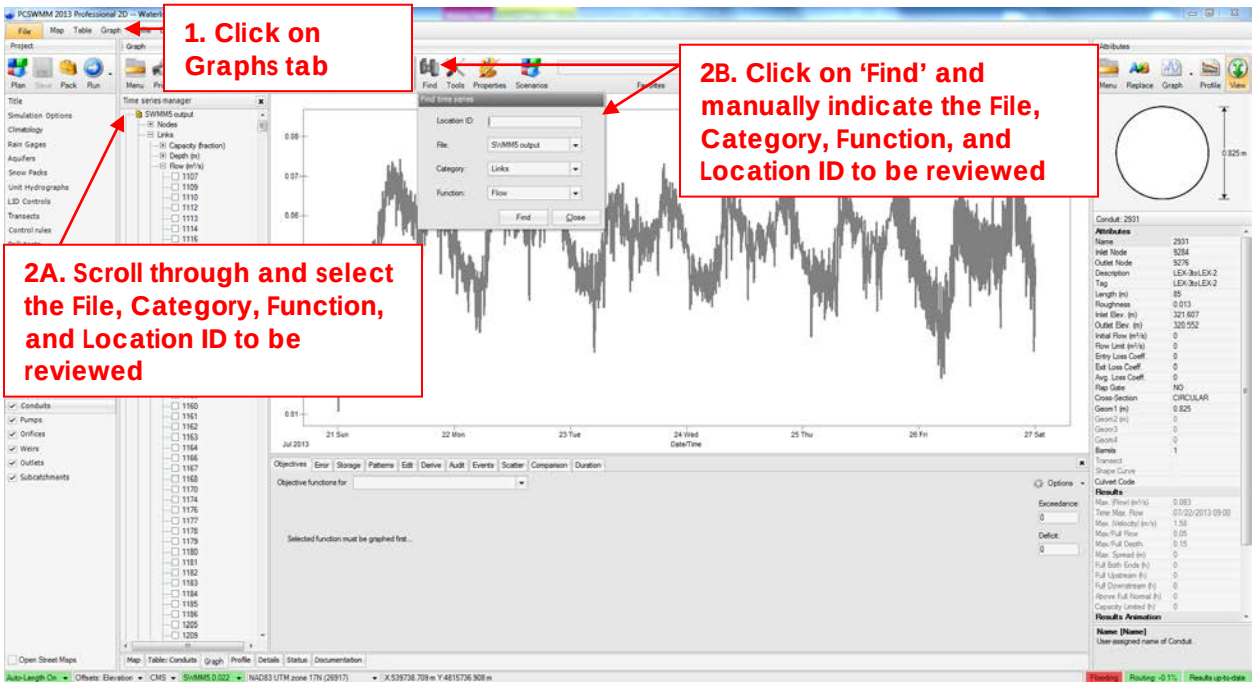
The steps to view the graphical results from the Graph tab are provided below:

1. Click on the Graphs tab.

2A. Under Time series manager, scroll through and select the File, Category, Function, and Location ID for the item to be reviewed.

OR

2B. Use the 'Find' option to manually input the Location ID, File, Category and Function to be reviewed.


1. Click on Graphs tab
2B. Click on 'Find' and manually indicate the File, Category, Function, and Location ID to be reviewed
2A. Scroll through and select the File, Category, Function, and Location ID to be reviewed

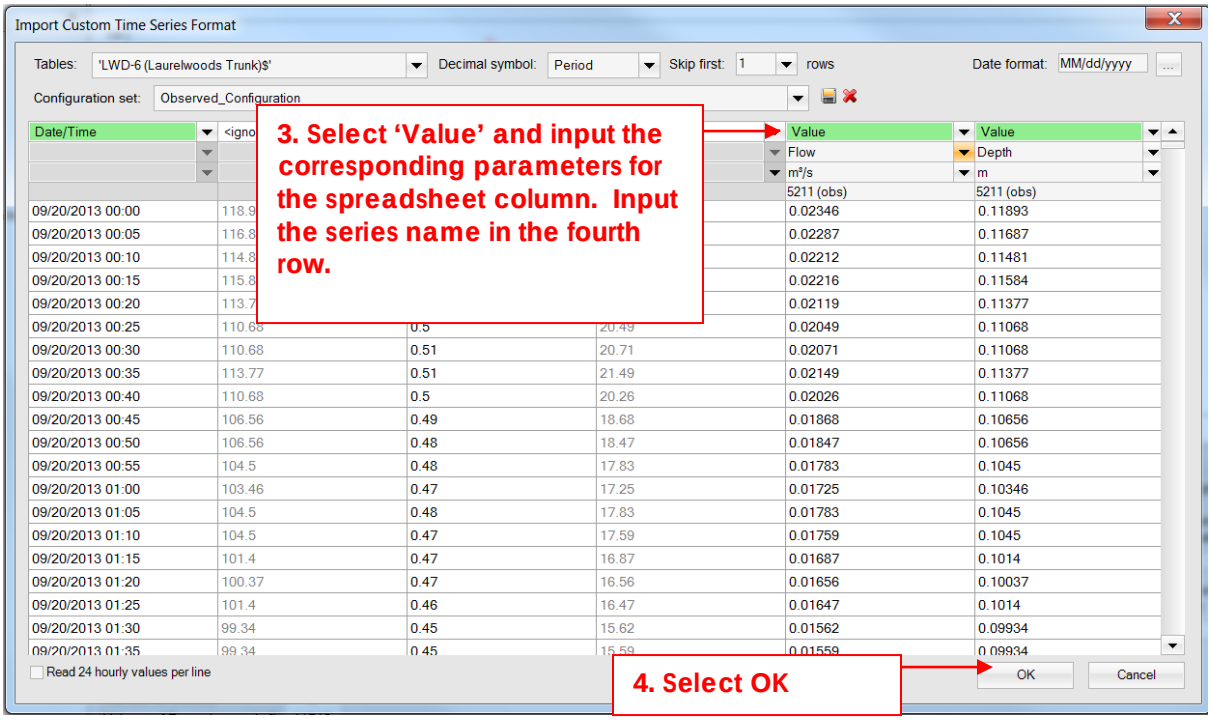
The observed flow monitoring data and rainfall data can be displayed alongside the modeling results (data source specified under 'File' selection). To view the observed data within the model, the rainfall and observed flows must first be imported. Steps to import the observed data are provided below:

1. Under the Graph tab, select Open.

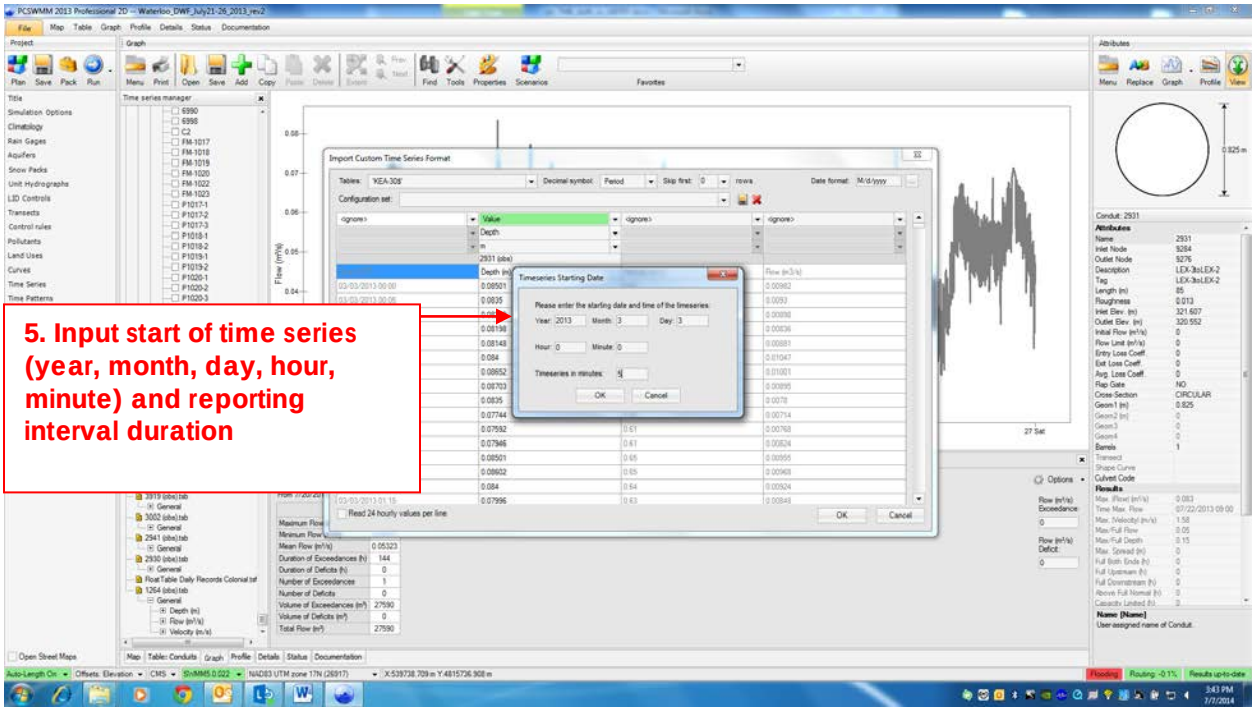
2. Select the spreadsheet with the time series data to be imported and an 'Import Custom Series Format' dialogue box will appear.

3. Select the 'Value' option and the corresponding input parameters to match the spreadsheet columns for the first three drop down boxes per column. In the fourth row for a given column, type the name to appear for the data file. Note: The naming convention used for flow monitoring data is the conduit ID number followed by '(obs)'. This allows the user to easily compare the modeled versus observed data for a given conduit.

4. Select OK.



5. Input the time series duration information in the 'Timeseries Starting Date' dialogue box based on the data series.


5. Input start of time series (year, month, day, hour, minute) and reporting interval duration
Import Custom Time Series Format
Timeseries Starting Date
Please enter the starting date and time of the timeseries
Timeseries in minutes:
OK
Cancel

Once the observed data file has been imported, it will appear under 'Time Series Manager' on the left hand side of the Graph Window. The observed data can be graphed using the same steps as those used to graph modeling results, with the exception of a different 'File' reference (i.e. SWMM5 output is the 'File' name for modeling results and the name assigned when saving/ importing the time series data is the 'File' name for the observed data (i.e. 5211 (obs)).

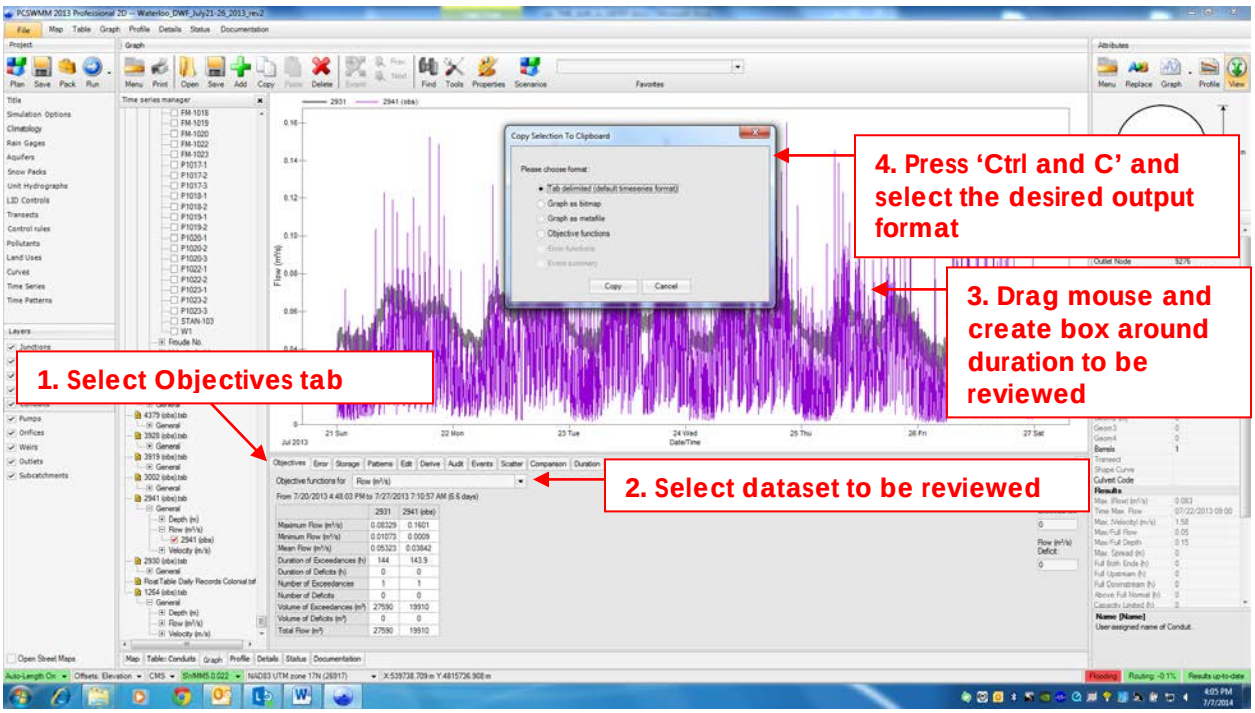
The 'Objectives' tab summarizes data statistics for graphed results. Steps to review the data statistics are provided below:

1. Within the Graph Window, select the Objectives tab.

2. Select the dataset to be reviewed using the pull down menu under 'Objective functions for' (i.e. flow, depth, velocity, etc.).

3. Use your mouse and click to create a box in the viewing window around the duration to be summarized for the objective functions.

4. Press 'Ctrl' and 'C' and select the desired output format to copy data from the Objective Functions (i.e. to document results in an Excel Spreadsheet).

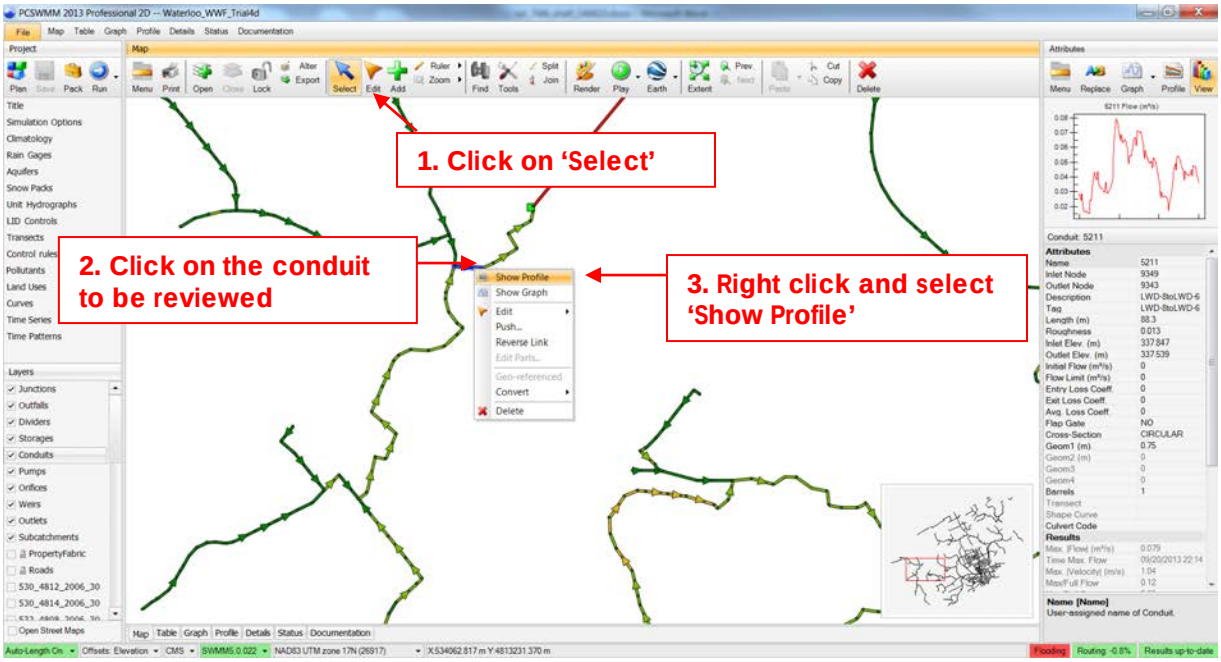

4. Press 'Ctrl and C' and select the desired output format
3. Drag mouse and create box around duration to be reviewed
1. Select Objectives tab
2. Select dataset to be reviewed

7.5.4.3 Viewing Results in Profile Form

PCSWMM allows profiles to be animated over a timeseries to visually review the water levels within conduits and any surcharges that may occur. It also allows the user to show the peak values that are associated with a given pipe (note this may not occur for each pipe at the same time step).

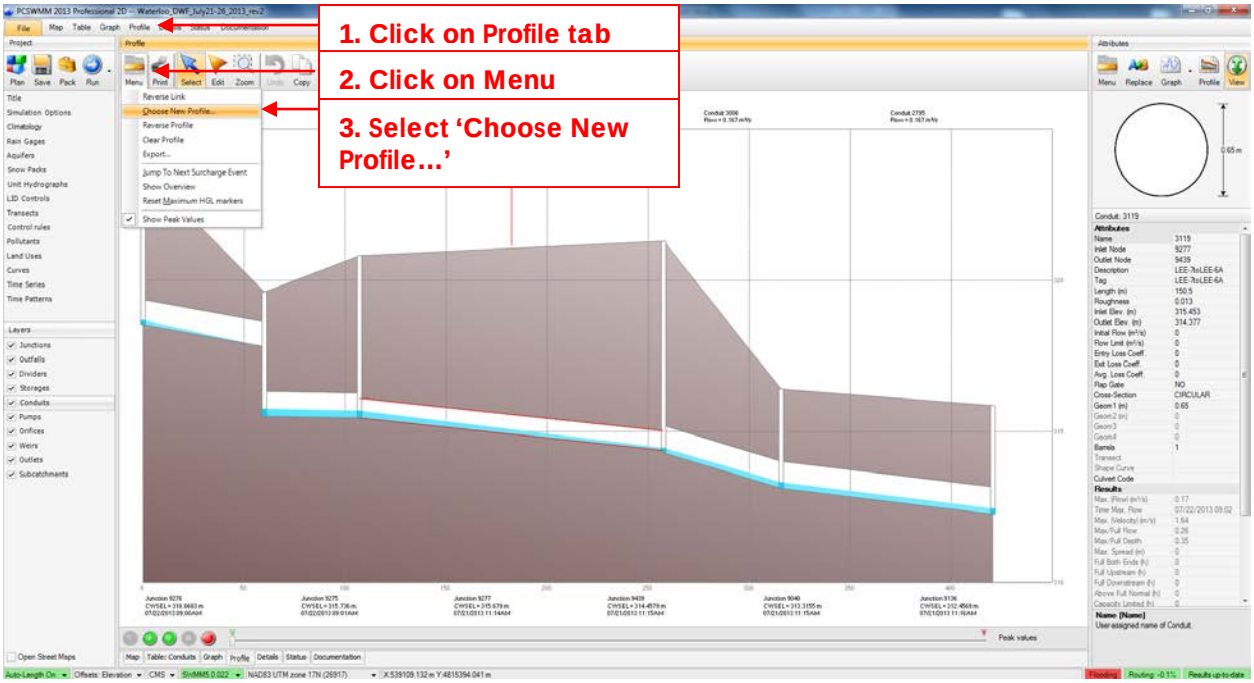
Steps to view the profile for a given conduit are provided below:

1. Within the Maps Window, click 'Select' under the Maps tools.
2. Click on the conduit to be reviewed.
3. Right Click and select 'Show Profile'.

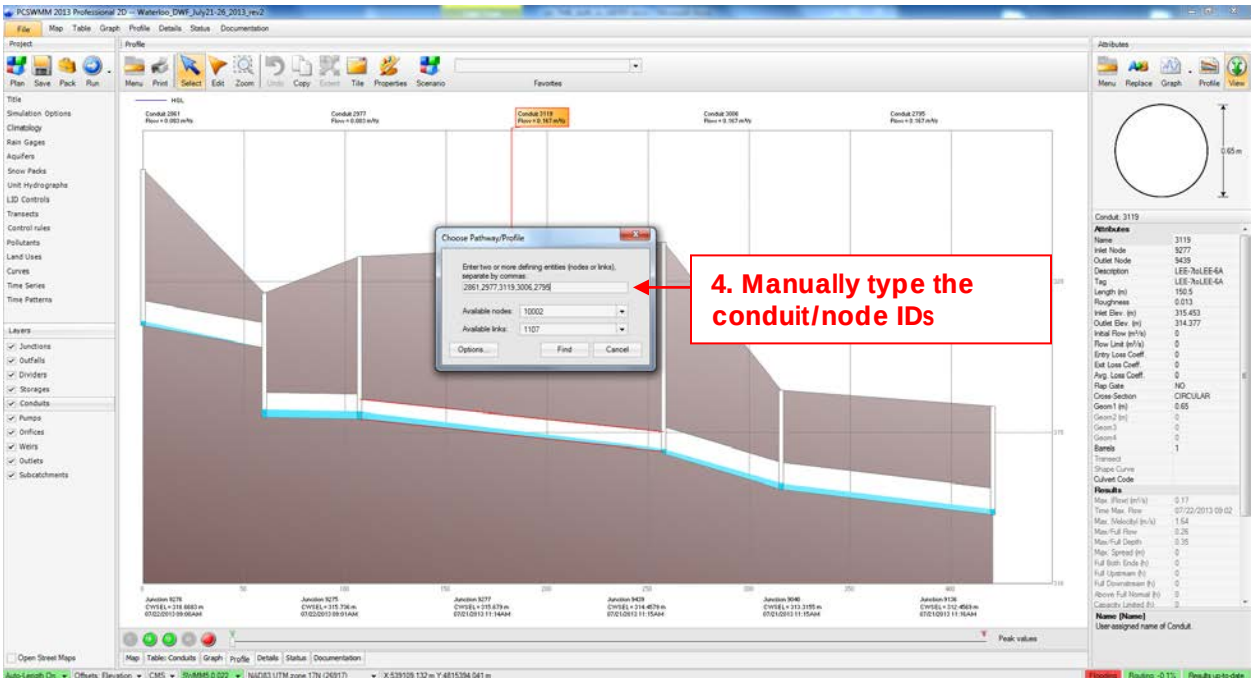


To manually specify a series of pipes to be graphed, the 'Choose New Profile' function can be used. Steps to use this function are provided below:

1. Click the Profile tab.
2. Click Menu.
3. Select 'Choose New Profile' and the 'Choose Pathway/Profile' dialogue box will appear.



4. Manually type the conduit/junction IDs to be included in the profile review. The user can input each ID, or specify only the most upstream and downstream node IDs for the profile.



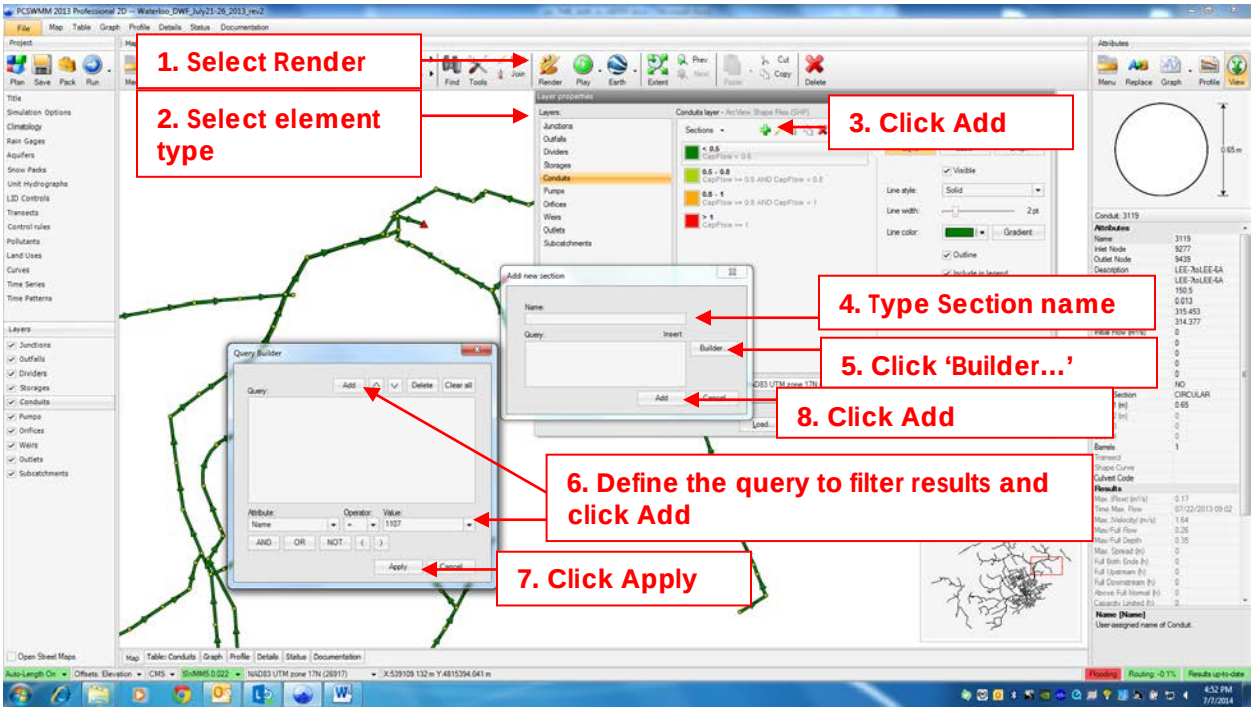
The profile will then appear in the profile window; however, PCSWMM may take a moment to load the time series for the selected elements. A toolbar below the profile allows the user to play the animation and identify times of high/low water elevations. The user may change which fields are displayed on the screen by right clicking on the profile and selecting properties. The user may then select various fields to be displayed.

7.5.4.4 Rendering

Elements can be colour coded to represent different input attributes or result fields. This allows the user to graphically display and easily review input parameters or model results throughout the collection system. Any of the fields within the table can be used for rendering.

Steps to colour code elements within the model are provided below:

1. Under the Map Window, Select the Render tool.
2. Under Layers, select the element type to be colour coded (i.e. junctions, conduits, etc.).
3. Click ‘Add’ to manually define sections to apply colour coding.
4. Type the name of the Section.
5. Click ‘Builder…’ and the ‘Query Builder’ dialogue box will appear.
6. Define the query to filter results or input attributes for the Section and Click ‘Add’.
7. Click ‘Apply’ in the ‘Query Builder’ dialogue box.
8. Click ‘Add’ under the ‘Add new section’ dialogue box.


1. Select Render
2. Select element type
3. Click Add
4. Type Section name
5. Click 'Builder…'
8. Click Add
6. Define the query to filter results and click Add
7. Click Apply

Typical results used to review the collection system performance are indicated below for conduits and junctions.

Conduits:

- Max/Full Depth – indicates the maximum depth in the sewer versus the full depth (d/D ratio).
- Max/Full Flow - indicates the maximum flow in the sewer versus the full flow capacity (q/Q ratio).

Junctions:

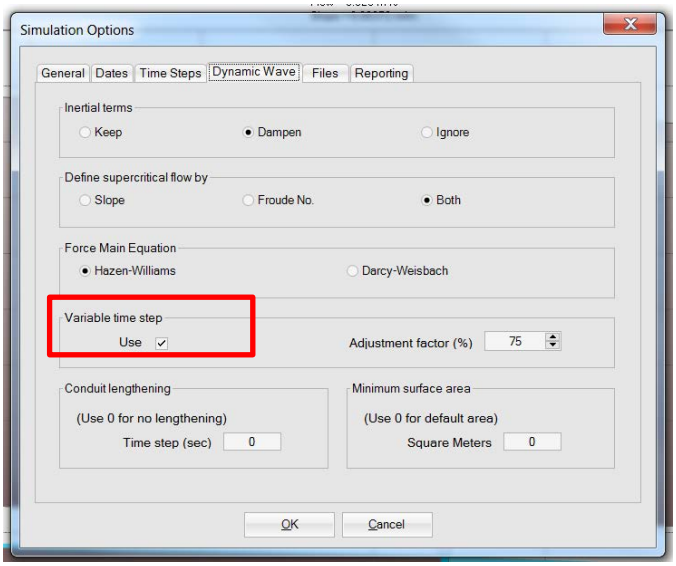
- Min Freeboard - represents the depth measured from the manhole rim to the maximum water elevation. Note that surcharges that exceed the ground/rim elevation are reported as zeroes.
- Max Surcharge – represents depth measured from the maximum HGL to the ground/ rim elevation.

7.5.4.5 Discrepancies in Results Due to a Variable Time Step

Results may be viewed in tables, graphs, or animated profiles; however, it should be noted that there may be discrepancies between the results viewed in these three manners. The table shows the resulting statistics based on the routing time step, whereas the graph and profile show the

results based on the output time series (i.e. the reported time step). The routing time step and the reporting time steps are defined in the simulation options window.

The routing time step is often smaller than the reporting time step, which is the cause of the discrepancy. The reporting timestep may be set equal to the routing timestep, which would eliminate the discrepancy, unless the 'Variable Time Step: Use' option is selected (as indicated below). A variable time step is recommended because it allows PCSWMM to reduce the time step as needed to aid in computation.



7.6 NEXT STEPS

The purpose of developing and calibrating the hydraulic model was to evaluate the capacity of the existing system and develop recommendations to accommodate growth up to the 2029 planning horizon (Task 7: Master Planning). Prior to completing this evaluation, a model scenario will be developed for the 2029 planning horizon. After all future scenarios have been finalized, the next steps will include:

- Identifying areas of concern and developing alternatives to address constraints.
- Developing opinions of probable cost for upgrade alternatives.
- Public consultation to obtain feedback and assist in the selection of preferred alternatives (Task 6).

The results of Master Planning Study (Task 7) will be summarized in a Final Report and filed for public review in accordance with the requirements for a Municipal Class Environmental Assessment.

Appendix A PHYSICAL MODEL LINK-NODE NETWORK INPUT DATA

Appendix B SANITARY CALIBRATION AND VALIDATION

1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-001 CBA-12

Conduit: 5102

Diameter: 375 mm

Model Input Parameters

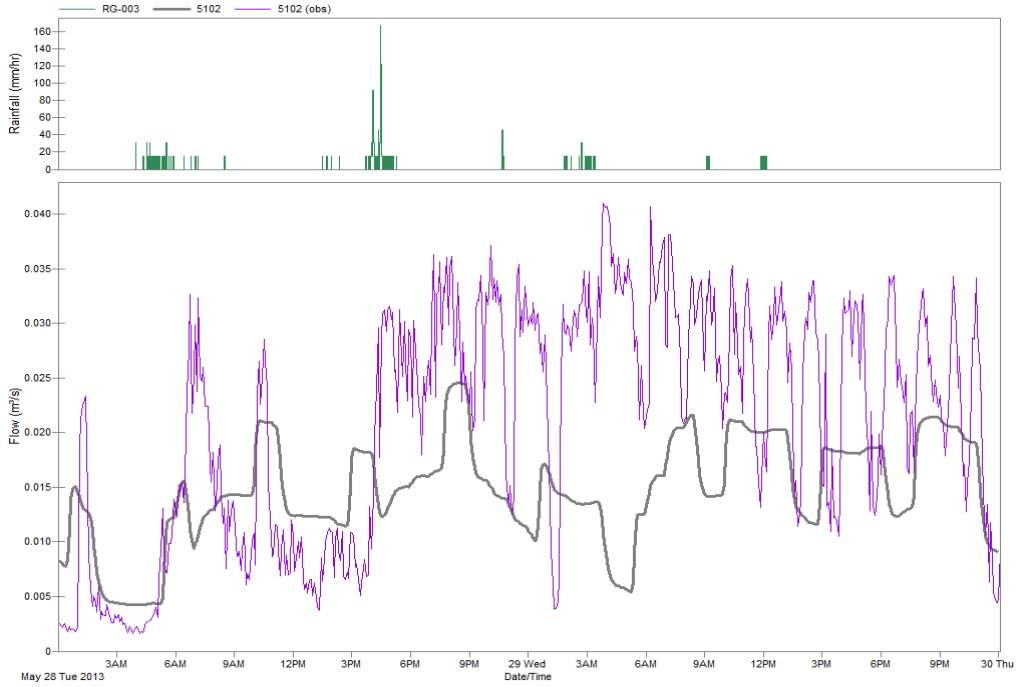
Parameter	1	2	3
R	0.008	0.001	0.001
T	0.35	12.00	24.00
K	35	5	4

R_{total}

1.0%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/28/2013 0:00	48.02	41.9	109.2	0.041	0.025	0.021	0.015	3611	2534
Difference (%)					-40%		-30%		-30%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

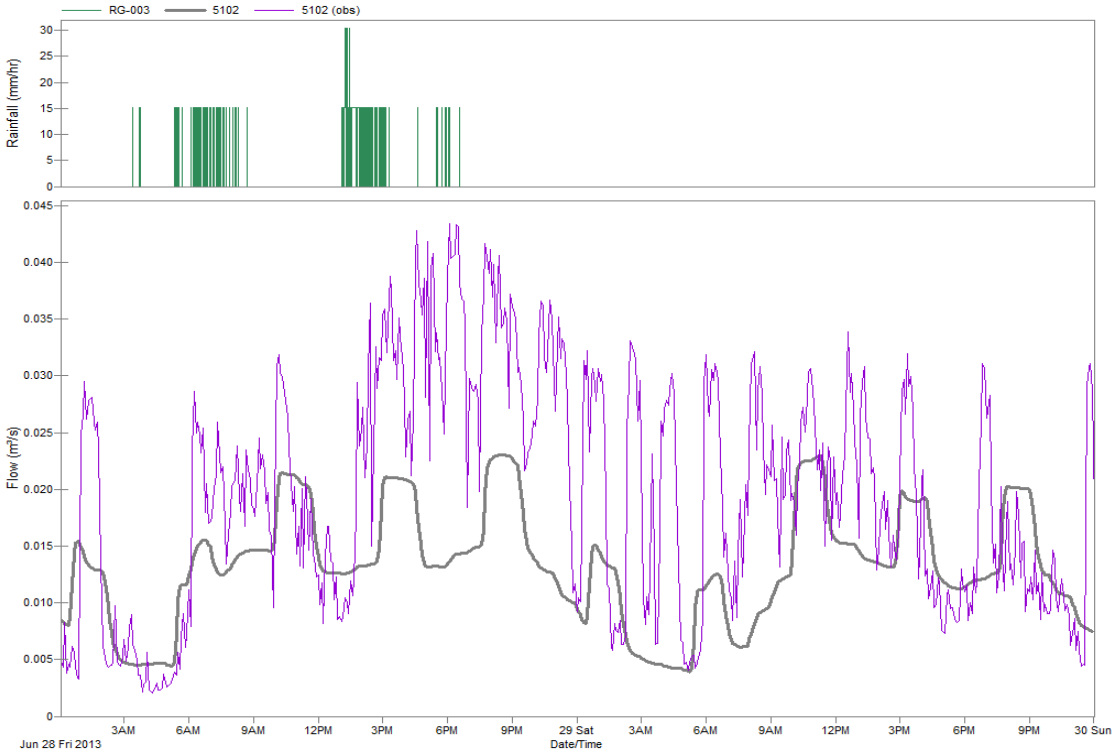
Monitor: FM-001 CBA-12

Conduit: 5102

Diameter: 375 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:02	47.95	31.6	39.6	0.043	0.023	0.020	0.013	3399	2271
Difference (%)					-47%		-33%		-33%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

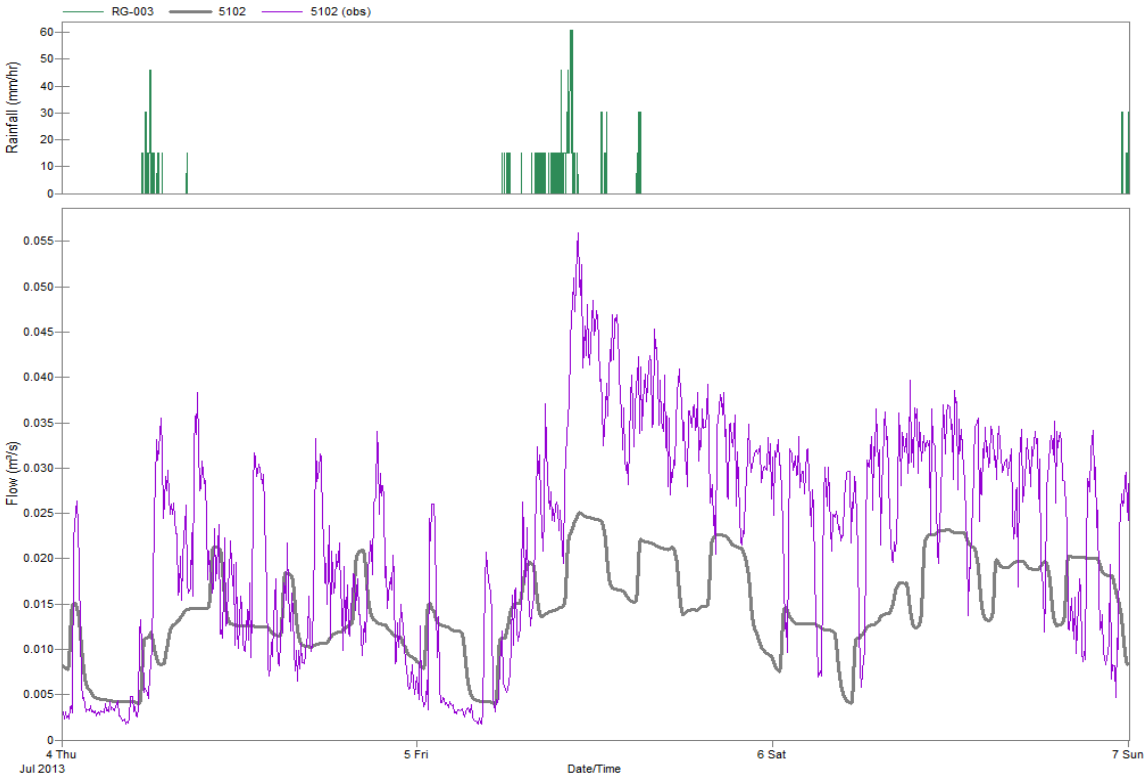
Monitor: FM-001 CBA-12

Conduit: 5102

Diameter: 375 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m³/s)	Current Max (m³/s)	Observed Mean (m³/s)	Current Mean (m³/s)	Observed Total (m³)	Current Total (m³)
7/3/2013 23:59	72	42.4	109.2	0.056	0.025	0.022	0.015	5833	3758
Difference (%)					-55%		-35%		-36%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

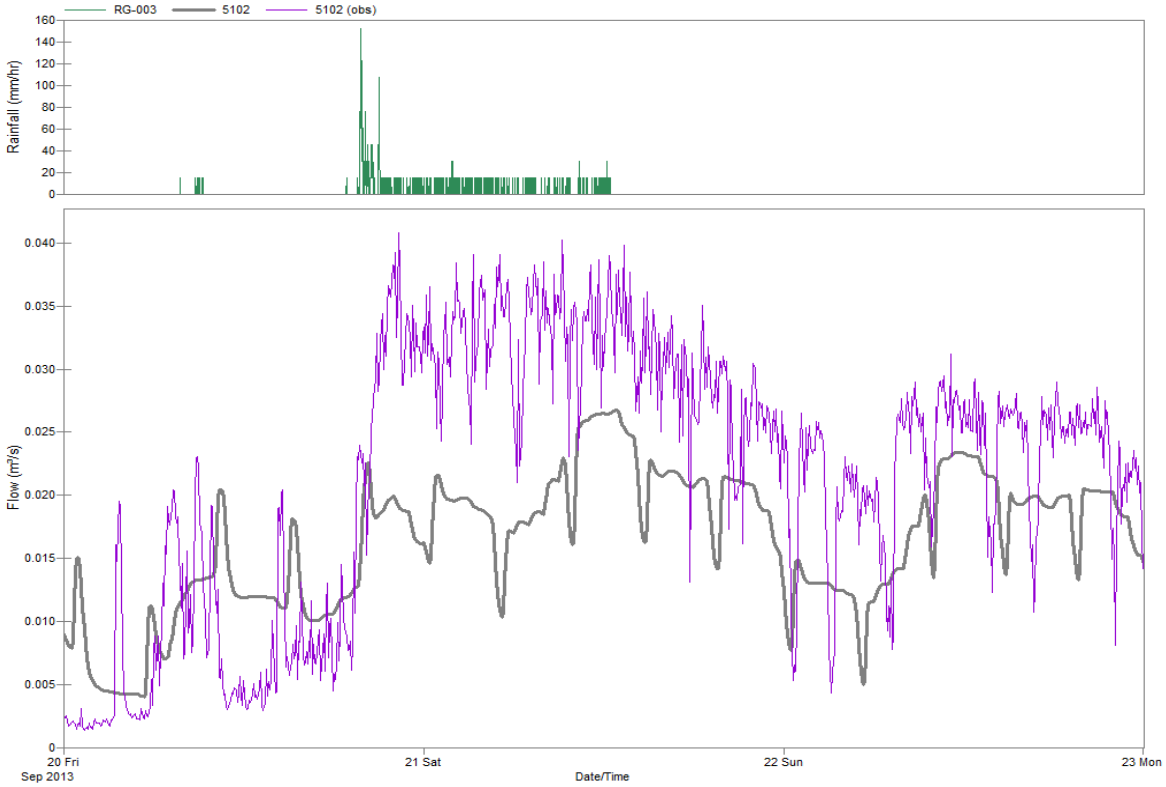
Monitor: FM-001 CBA-12

Conduit: 5102

Diameter: 375 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m³/s)	Current Max (m³/s)	Observed Mean (m³/s)	Current Mean (m³/s)	Observed Total (m³)	Current Total (m³)
9/19/2013 23:57	72	89.9	164.4	0.041	0.027	0.022	0.016	5619	4250
Difference (%)					-34%		-24%		-24%



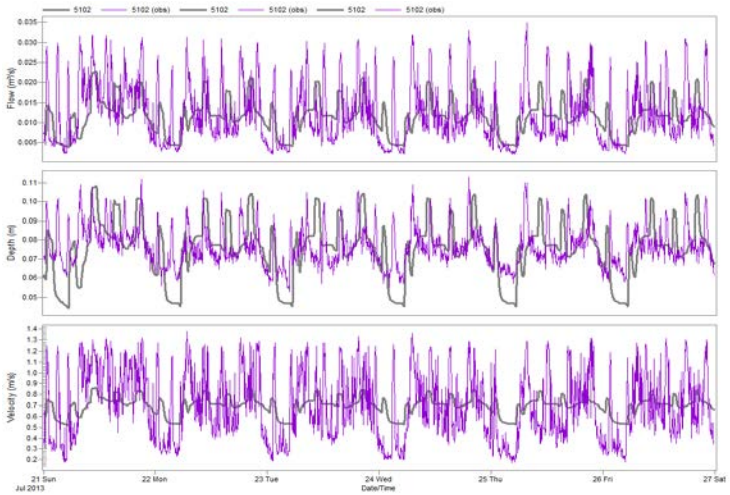
1611-11191: Waterloo Sanitary Master Plan

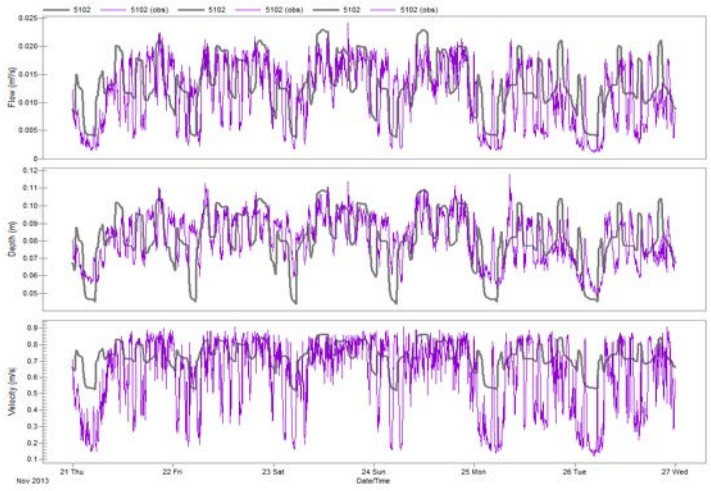
Dry Weather Calibration - Final

			Target %	
Monitor	FM-001	CBA-12	D_{max}	-20 to +20%
Conduit	5102		Q_{max}	-15 to +15%
			Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	July 21-26, 2013				November 21-26, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.023	0.023			0.023	0.023		
Base Flow (L/s)	1.25	1.27			1.25	1.27		
Population	2719	2719			2719	2719		
Per Capita (L/c/d)	253	270			253	270		
Avg. Sewage (L/s)	8.0	8.5			8.0	8.5		
Pipe (mm)	375	375			375	375		
Total Area (ha)	54.0	54.9			54.0	54.9		
Incremental Area (ha)	54.0	54.9			54.0	54.9		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.113	0.108	-0.005	-4%	0.118	0.109	-0.009	-8%
Q_{max} (m^3/s)	0.035	0.023	-0.012	-35%	0.024	0.023	-0.001	-5%
Vol (m^3)	6327	5947	-381	-6%	6033	6870	837	14%
Vel_{max} (m/s)	1.4	0.9	-0.5	-38%	0.9	0.9	0.0	-5%

Graph





1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-002 FWL-4A

Conduit: 3928

Diameter: 825 mm

Model Input Parameters

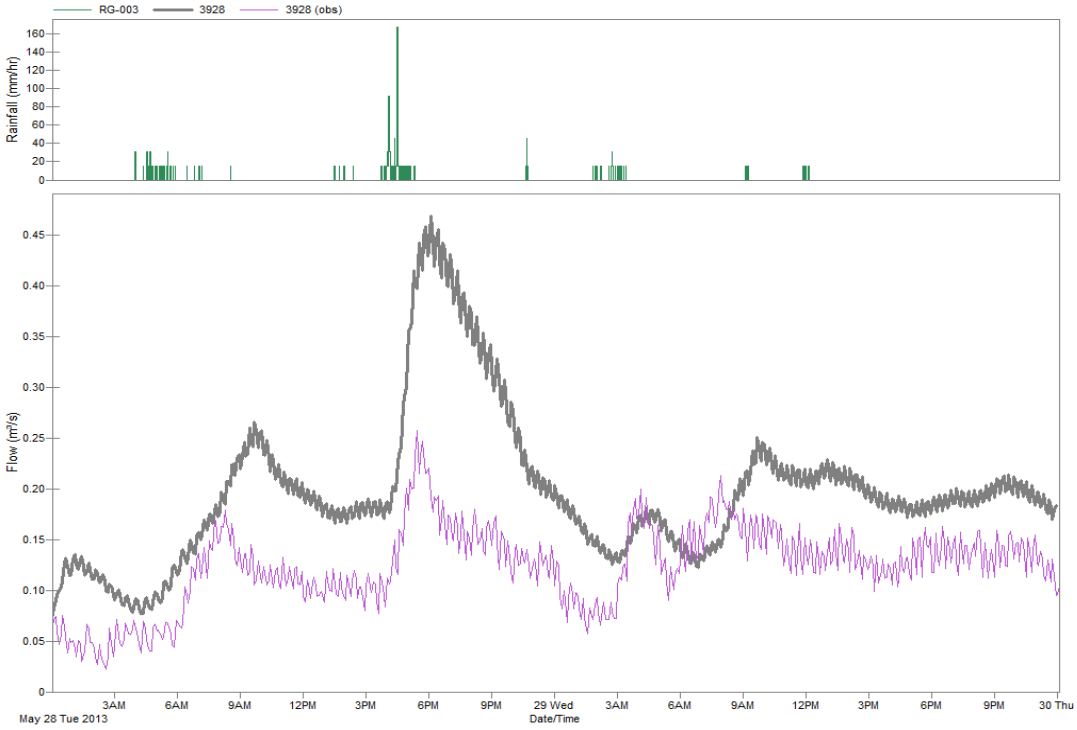
Parameter	1	2	3
R	0.025	0.005	0.001
T	0.21	12.00	24.00
K	28	5	4

R_{total}

3.1%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/27/2013 23:55	48.11	41.9	109.2	0.257	0.469	0.124	0.198	21390	34070
Difference (%)					82%		60%		59%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

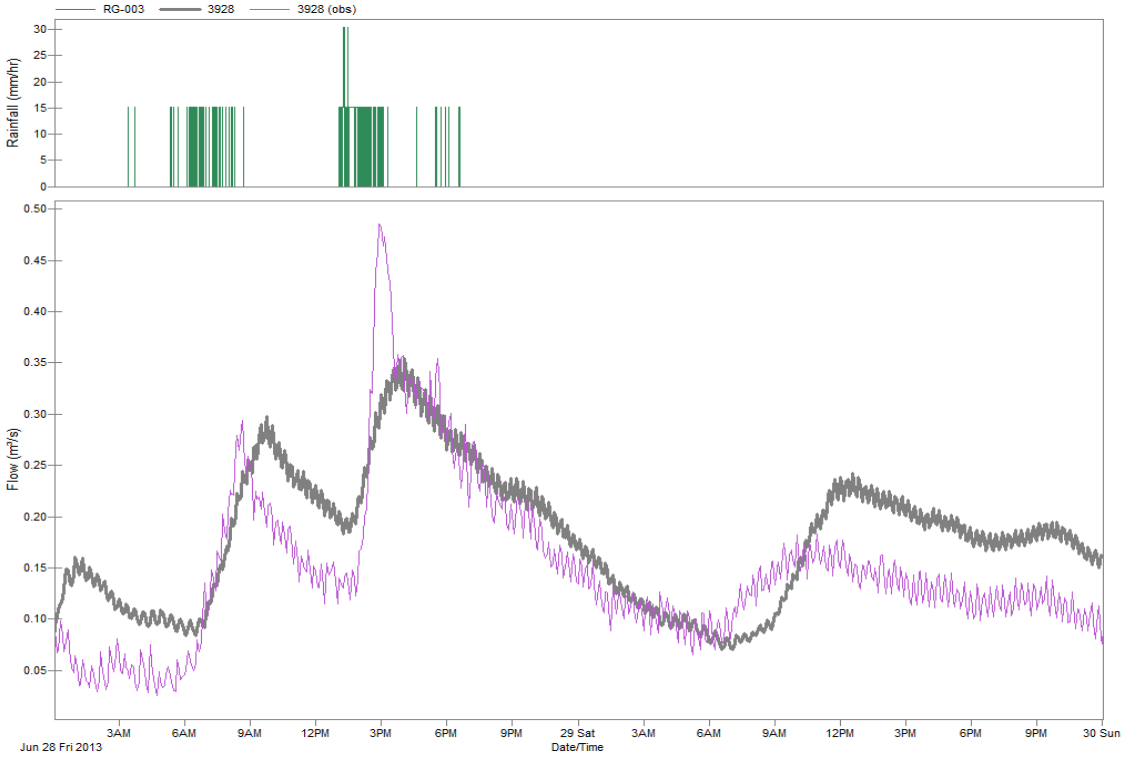
Monitor: FM-002 FWL-4A

Conduit: 3928

Diameter: 825 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:02	47.95	31.6	39.6	0.485	0.354	0.150	0.181	25860	31140
Difference (%)					-27%		21%		20%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

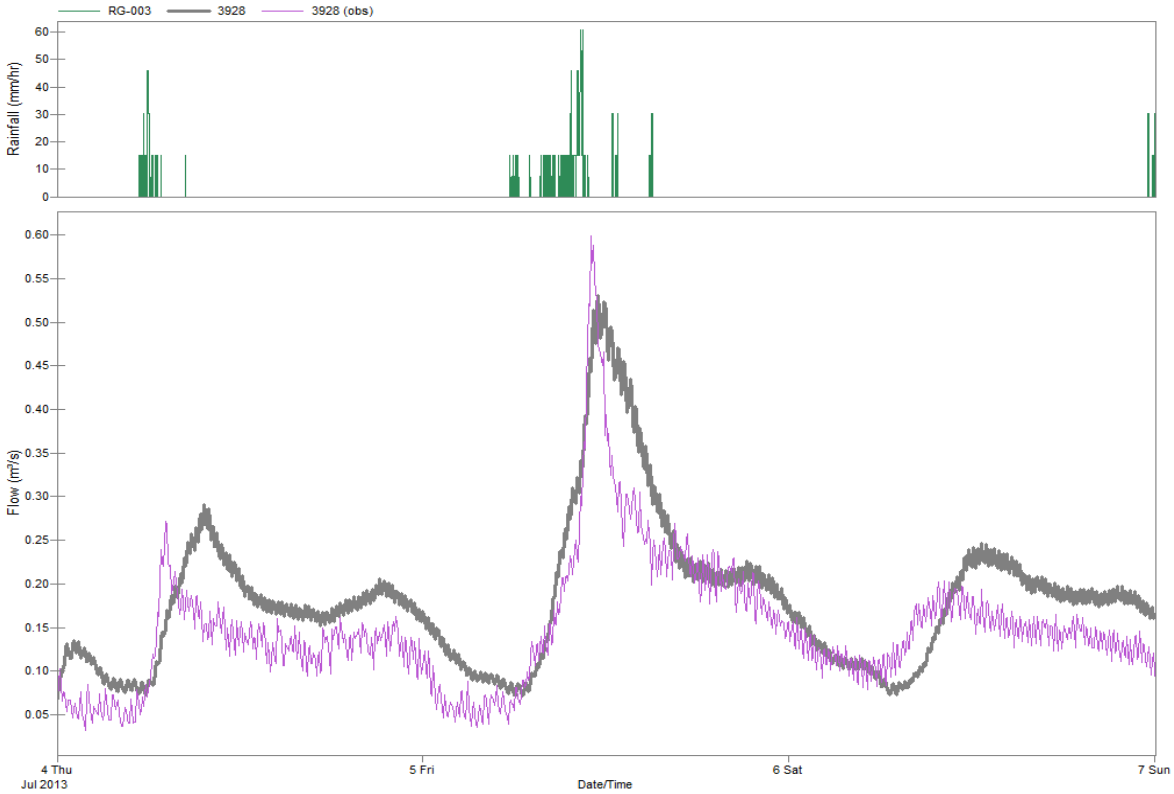
Monitor: FM-002 FWL-4A

Conduit: 3928

Diameter: 825 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:59	72	42.4	109.2	0.599	0.531	0.150	0.184	38790	47510
Difference (%)					-11%		23%		22%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

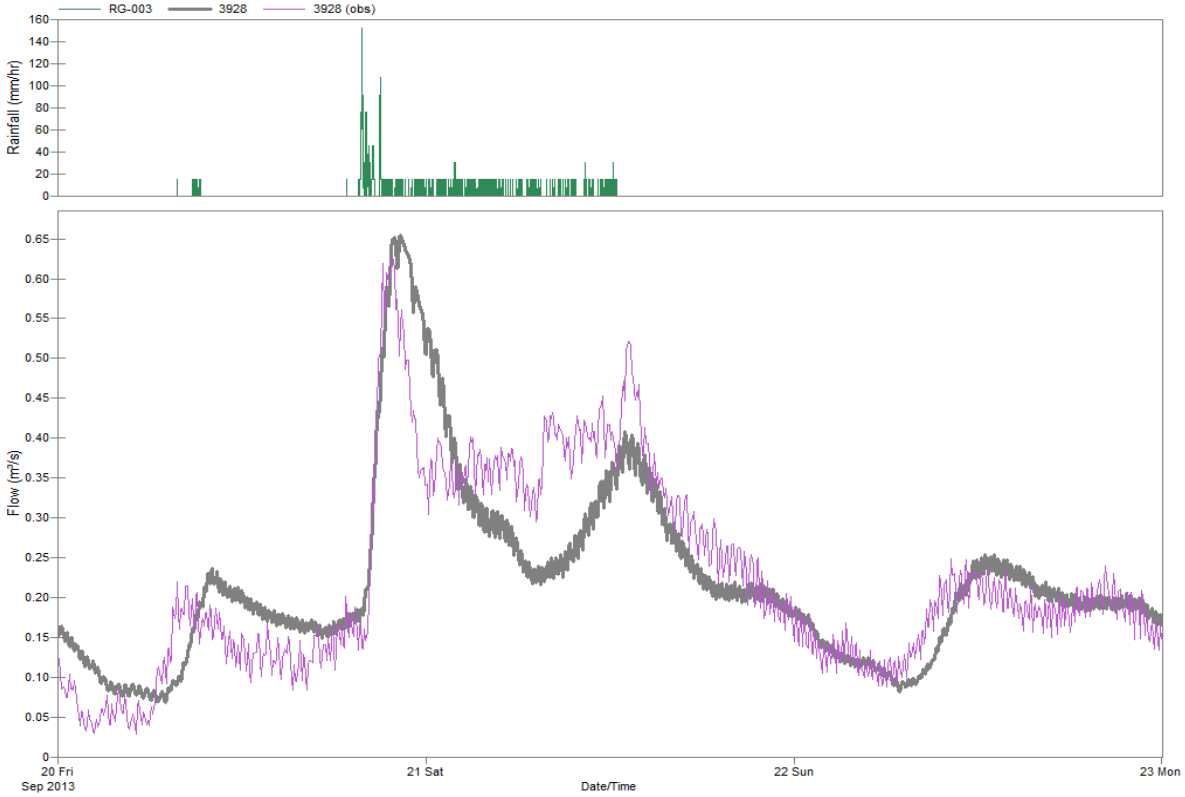
Monitor: FM-002 FWL-4A

Conduit: 3928

Diameter: 825 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
9/19/2013 23:57	72	89.9	164.4	0.630	0.655	0.226	0.222	58470	57490
Difference (%)					4%		-2%		-2%



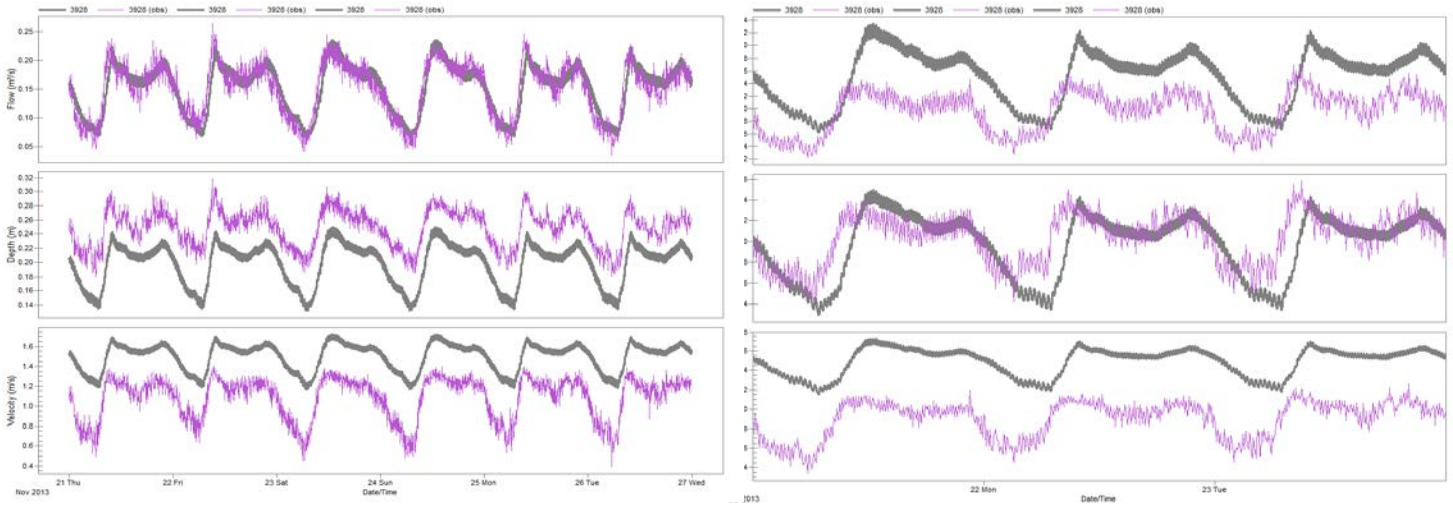
1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

	Target %			
Monitor:	D_{max}	-20 to +20%	FM-002	FWL-4A
Conduit:	Q_{max}	-15 to +15%	3928	
	Vol	-20 to +20%		

	Calibration Event				Validation Event			
Date	Date	November 21-26, 2013			July 21-26, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.019	0.019			0.019	0.019		
Base Flow (L/s)	6.48	6.37			6.48	6.37		
Population	18631	18622			18631	18622		
Per Capita (L/c/d)	312	312			312	312		
Avg. Sewage (L/s)	67.3	67.3			67.3	67.3		
Pipe (mm)	825	825			825	825		
Total Area (ha)	886.0	886.0			886.0	886.0		
Incremental Area (ha)	339.6	333.7			339.6	333.7		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.319	0.250	-0.069	-22%	0.261	0.250	-0.011	-4%
Q_{max} (m^3/s)	0.265	0.236	-0.030	-11%	0.173	0.236	0.062	36%
Vol (m^3)	78187	78458	271	0%	49457	77542	28085	57%
Vel_{max} (m/s)	1.4	1.7	0.3	22%	1.3	1.7	0.5	36%

Graph



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-003 GLN-4

Conduit: 3919

Diameter: 450 mm

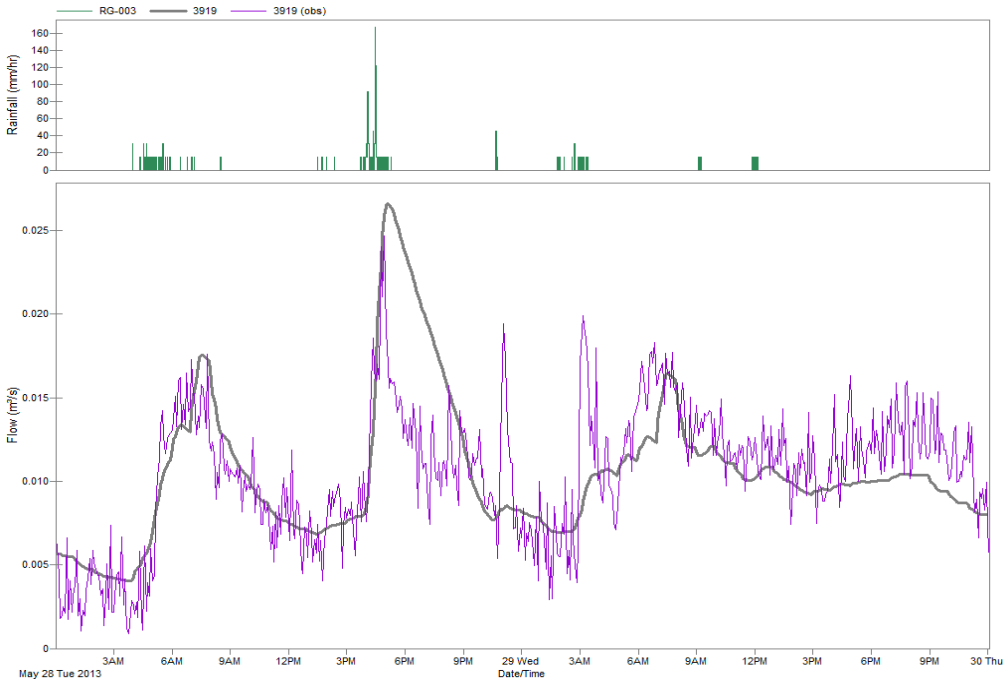
Model Input Parameters

Parameter	1	2	3
R	0.020	0.020	0.010
T	0.15	10.00	24.00
K	35	10	4

R_{total} 5.0%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/28/2013 0:00	48.05	41.9	109.2	0.025	0.027	0.010	0.010	1814	1809
Difference (%)					8%		0%		0%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

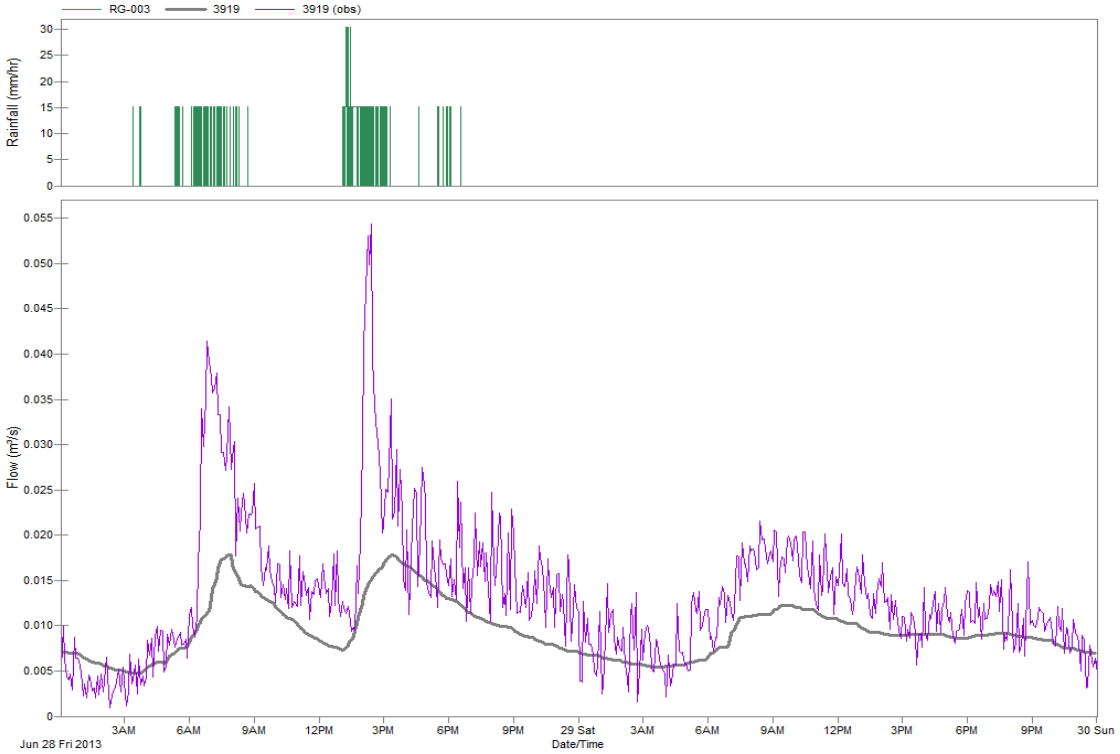
Monitor: FM-003 GLN-4

Conduit: 3919

Diameter: 450 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:02	47.95	31.6	39.6	0.054	0.018	0.013	0.009	2329	1629
Difference (%)					-67%		-30%		-30%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

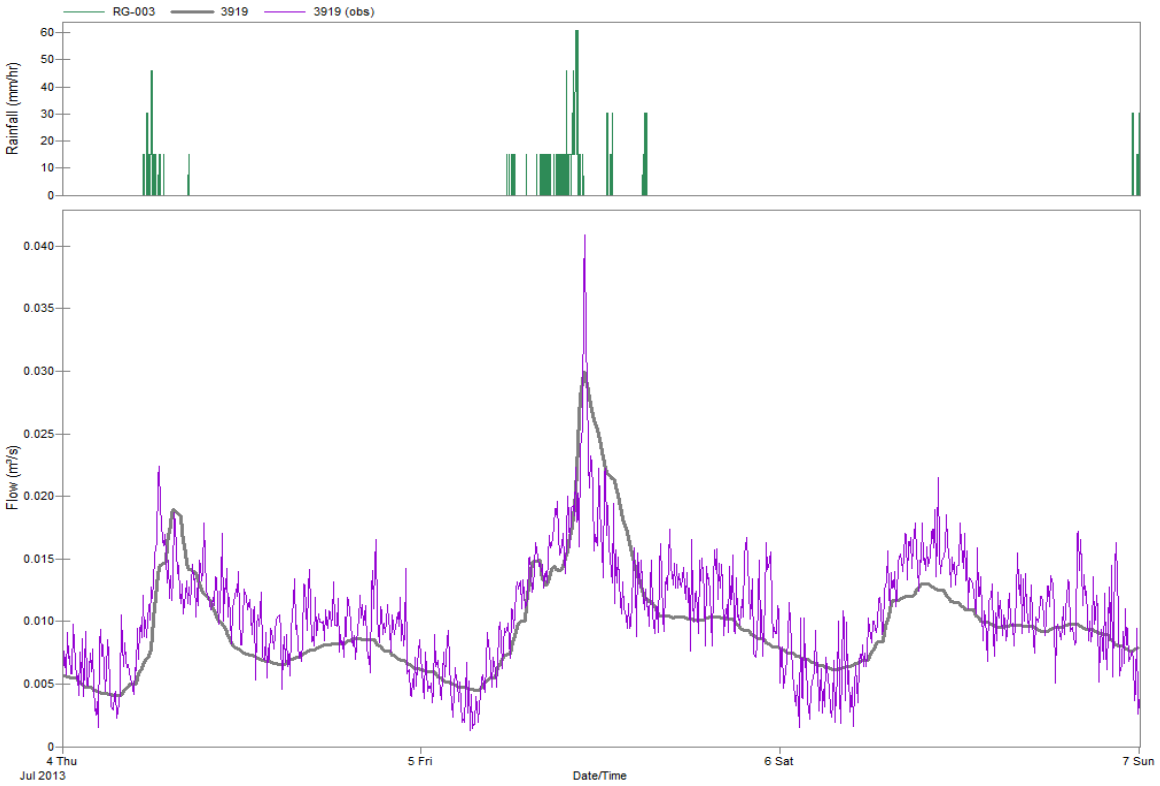
Monitor: FM-003 GLN-4

Conduit: 3919

Diameter: 450 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m³/s)	Current Max (m³/s)	Observed Mean (m³/s)	Current Mean (m³/s)	Observed Total (m³)	Current Total (m³)
7/3/2013 23:59	72	42.4	109.2	0.041	0.030	0.011	0.010	2764	2512
Difference (%)					-27%		-9%		-9%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

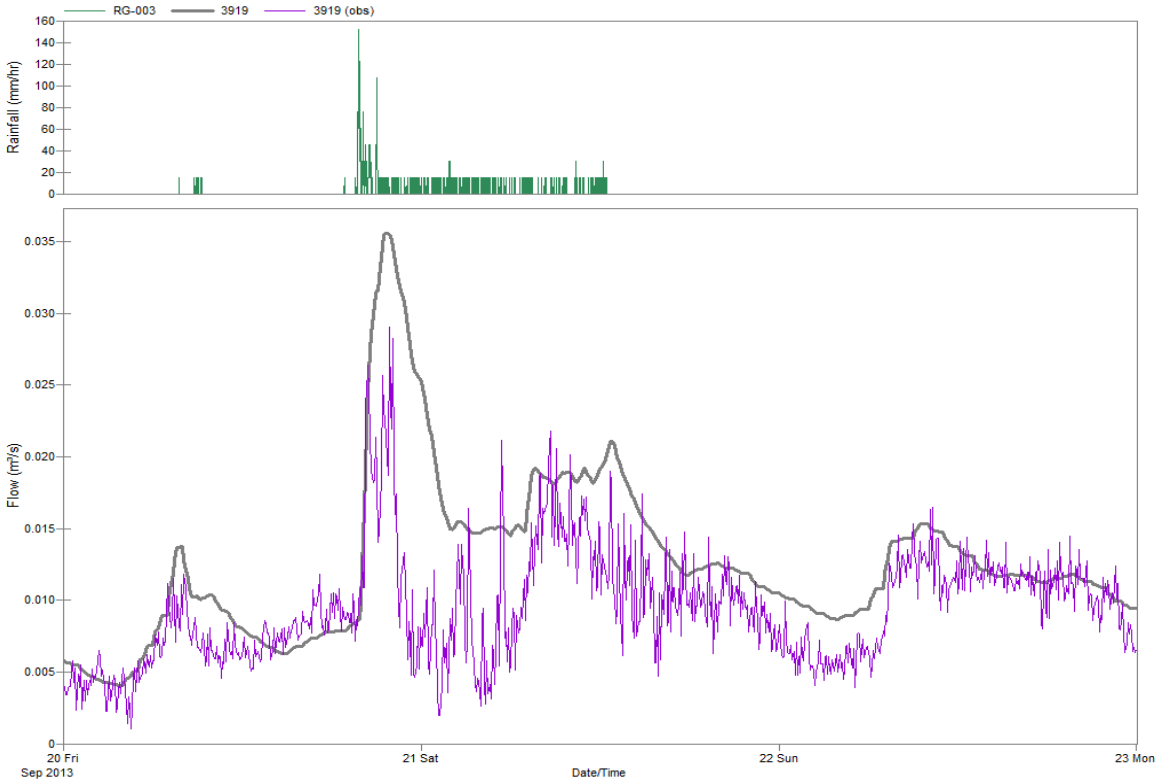
Monitor: FM-003 GLN-4

Conduit: 3919

Diameter: 450 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m³/s)	Current Max (m³/s)	Observed Mean (m³/s)	Current Mean (m³/s)	Observed Total (m³)	Current Total (m³)
9/19/2013 23:57	72	89.9	164.4	0.029	0.036	0.009	0.013	2450	3296
Difference (%)					23%		34%		35%



1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

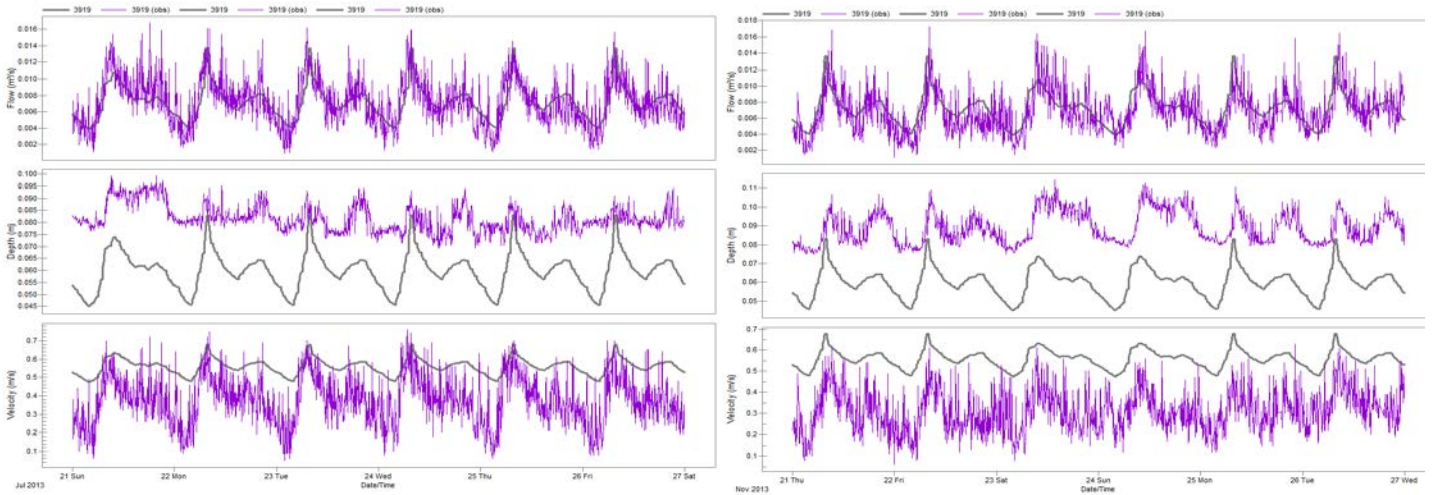
Monitor: FM-003 GLN-4

Conduit: 3919

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	July 21-26, 2013				Date	November 21-26, 2013		
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.049	0.049			0.049	0.049		
Base Flow (L/s)	2.13	2.05			2.13	2.05		
Population	2252	2252			2252	2252		
Per Capita (L/c/d)	182	197			182	197		
Avg. Sewage (L/s)	4.7	5.1			4.7	5.1		
Pipe (mm)	450	450			450	450		
Total Area (ha)	43.5	42.0			43.5	42.0		
Incremental Area (ha)	43.5	42.0			43.5	42.0		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.099	0.083	-0.016	-16%	0.114	0.083	-0.031	-27%
Q_{max} (m^3/s)	0.017	0.014	-0.003	-19%	0.017	0.014	-0.004	-21%
Vol (m^3)	3753	3720	-33	-1%	3555	3715	160	5%
Vel_{max} (m/s)	0.8	0.7	-0.1	-11%	0.6	0.7	0.0	8%

Graph



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-004 LEE-9

Conduit: 2930

Diameter: 600 mm

Model Input Parameters

Parameter	1	2	3
R	0.010	0.010	0.010
T	0.30	7.00	24.00
K	38	6	4

R_{total}

3.0%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/28/2013 0:00	48.05	41.9	109.2	0.122	0.162	0.070	0.092	12080	15900
Difference (%)					33%		32%		32%

1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

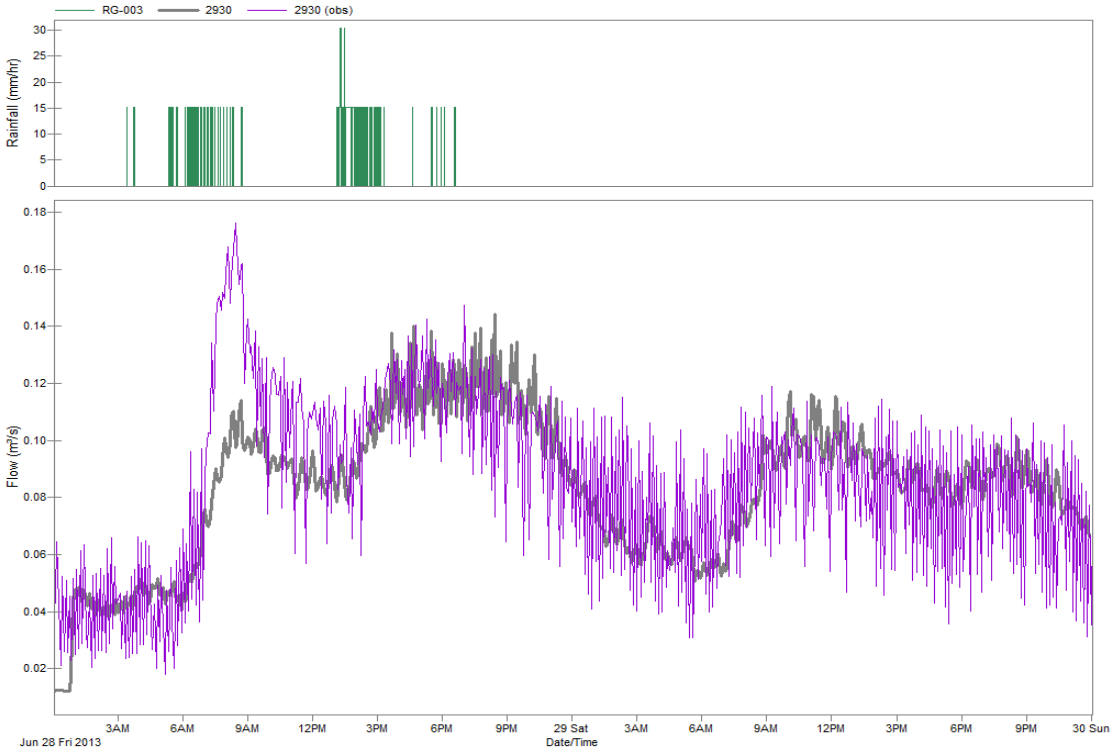
Monitor: FM-004 LEE-9

Conduit: 2930

Diameter: 600 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:01	48.02	31.6	39.6	0.176	0.144	0.085	0.084	14780	14420
Difference (%)					-18%		-2%		-2%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

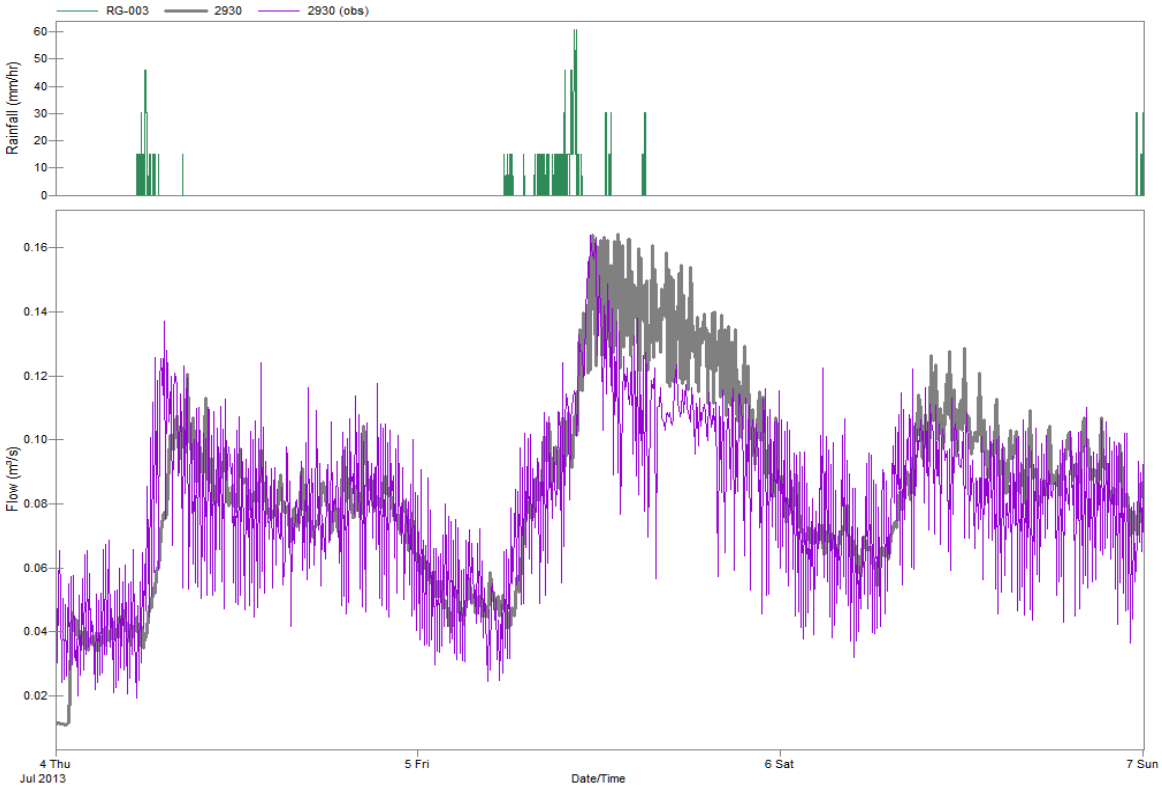
Monitor: FM-004 LEE-9

Conduit: 2930

Diameter: 600 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:59	72	42.4	109.2	0.164	0.164	0.081	0.086	20890	22220
Difference (%)					0%		7%		6%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

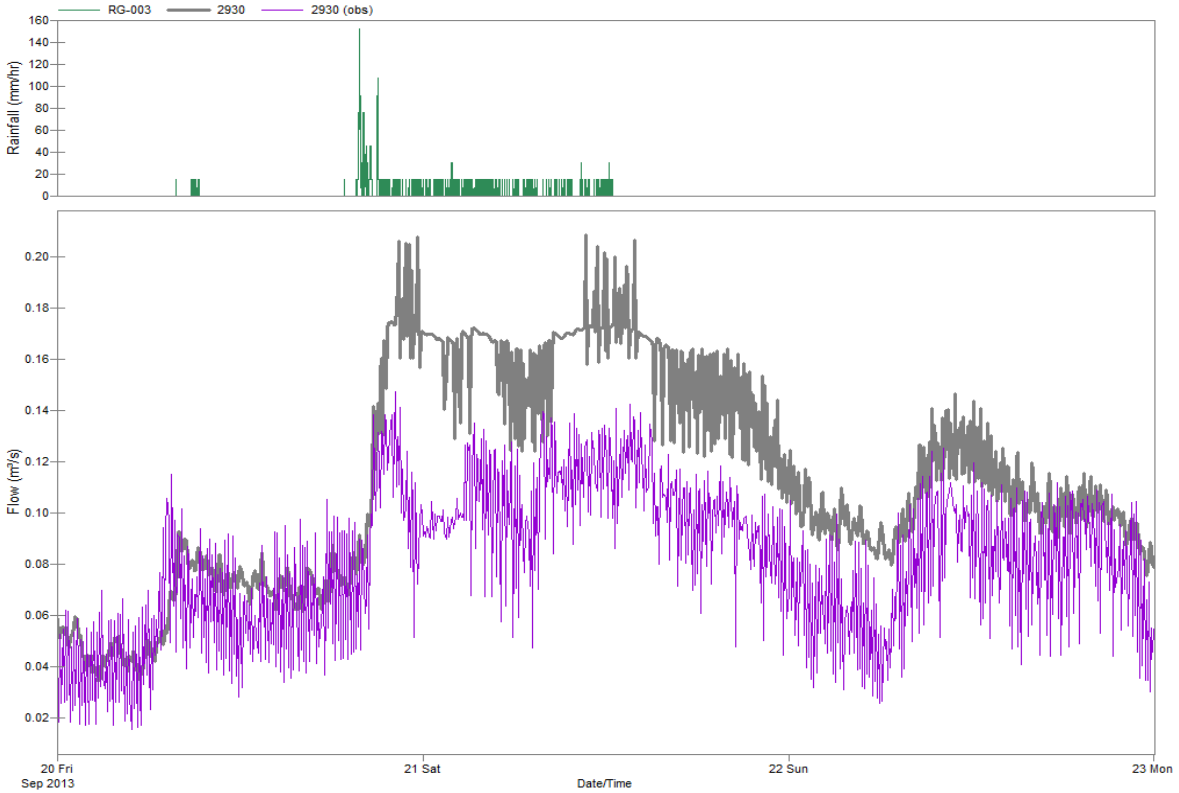
Monitor: FM-004 LEE-9

Conduit: 2930

Diameter: 600 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
9/19/2013 23:57	72	89.9	164.4	0.147	0.208	0.082	0.113	21220	29380
Difference (%)					42%		38%		38%



1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

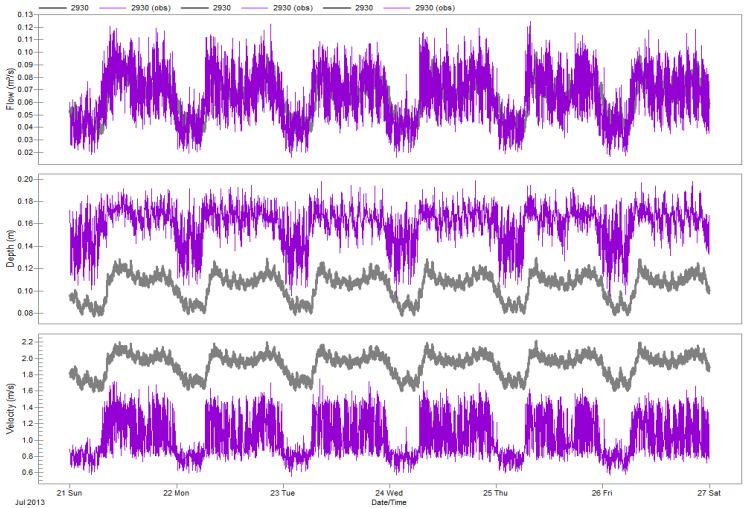
Monitor: FM-004 LEE-9

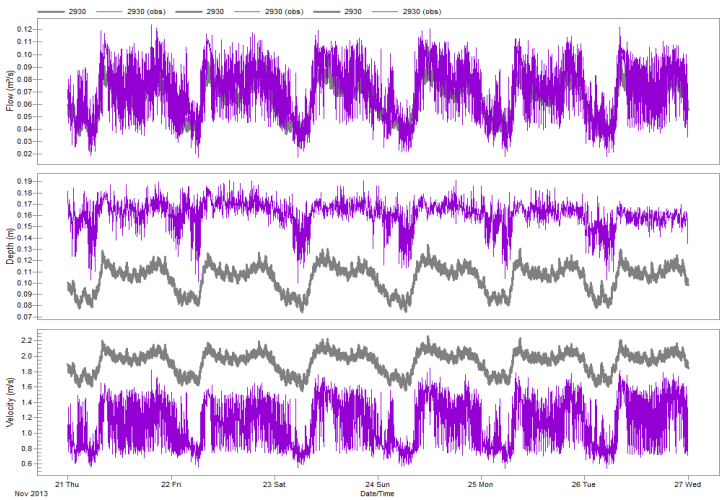
Conduit: 2930

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	July 21-26, 2013				November 21-26, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.033	0.035			0.033	0.035		
Base Flow (L/s)	18.03	18.00			18.03	18.00		
Population	25980	25980			25980	25980		
Per Capita (L/c/d)	148	150			148	150		
Avg. Sewage (L/s)	44.5	45.8			44.5	45.8		
Pipe (mm)	600	600			600	600		
Total Area (ha)	546.5	516.4			546.5	516.4		
Incremental Area (ha)	546.5	516.4			546.5	516.4		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.199	0.130	-0.069	-35%	0.192	0.134	-0.058	-30%
Q_{max} (m^3/s)	0.125	0.100	-0.025	-20%	0.124	0.106	-0.018	-15%
Vol (m^3)	33560	33365	-195	-1%	36497	33375	-3121	-9%
Vel_{max} (m/s)	1.8	2.2	0.5	27%	1.9	2.3	0.4	22%

Graph





1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-005 LEX-8A

Conduit: 2941

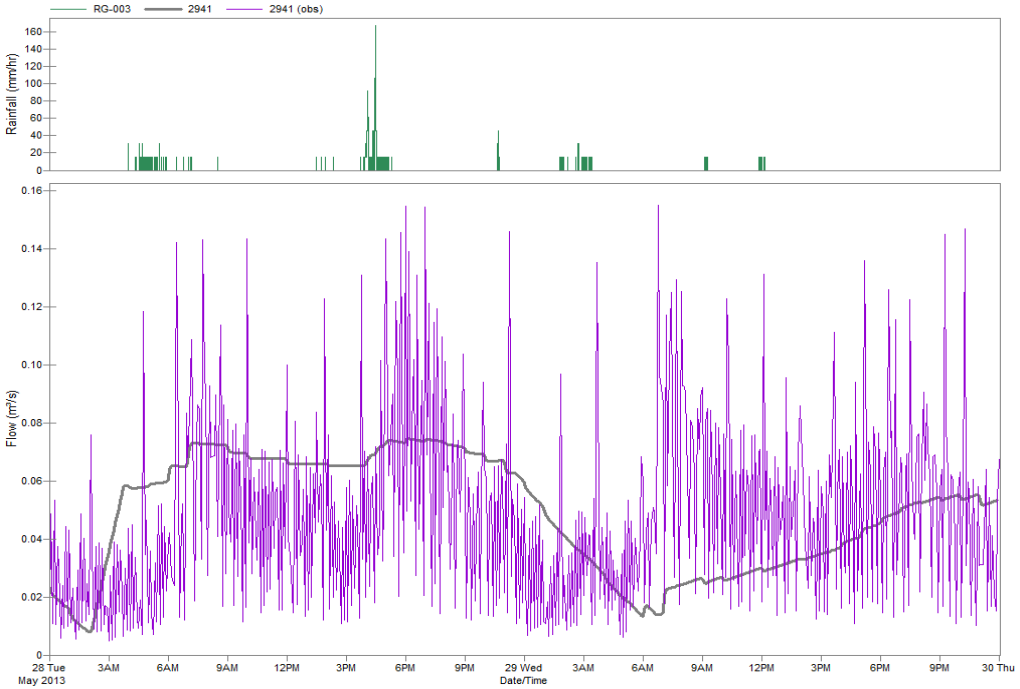
Diameter: 825 mm

Model Input Parameters

Parameter	1	2	3	R_{total}
R	0.020	0.020	0.010	5.0%
T	0.15	10.00	24.00	
K	35	10	4	

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/27/2013 23:59	48.04	41.9	109.2	0.155	0.074	0.049	0.049	8449	8407
Difference (%)					-52%		0%		0%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

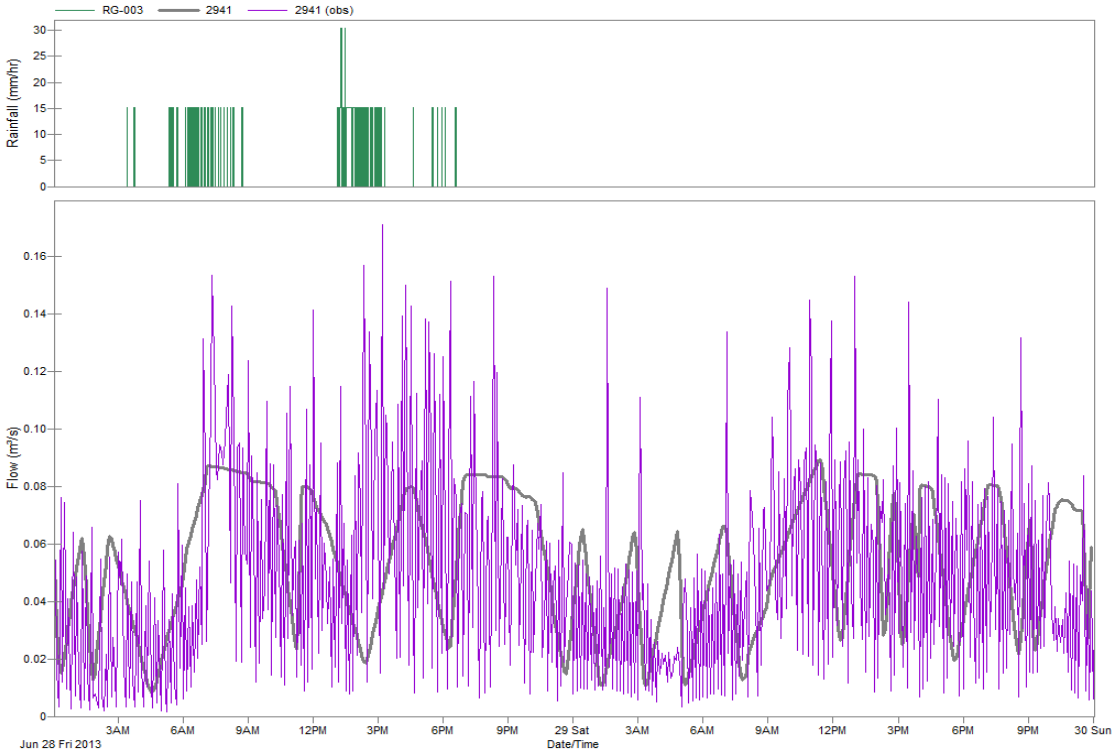
Monitor: FM-005 LEX-8A

Conduit: 2941

Diameter: 825 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m³/s)	Current Max (m³/s)	Observed Mean (m³/s)	Current Mean (m³/s)	Observed Total (m³)	Current Total (m³)
6/28/2013 0:01	48.02	31.6	39.6	0.171	0.089	0.049	0.053	8464	9198
Difference (%)					-48%		9%		9%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

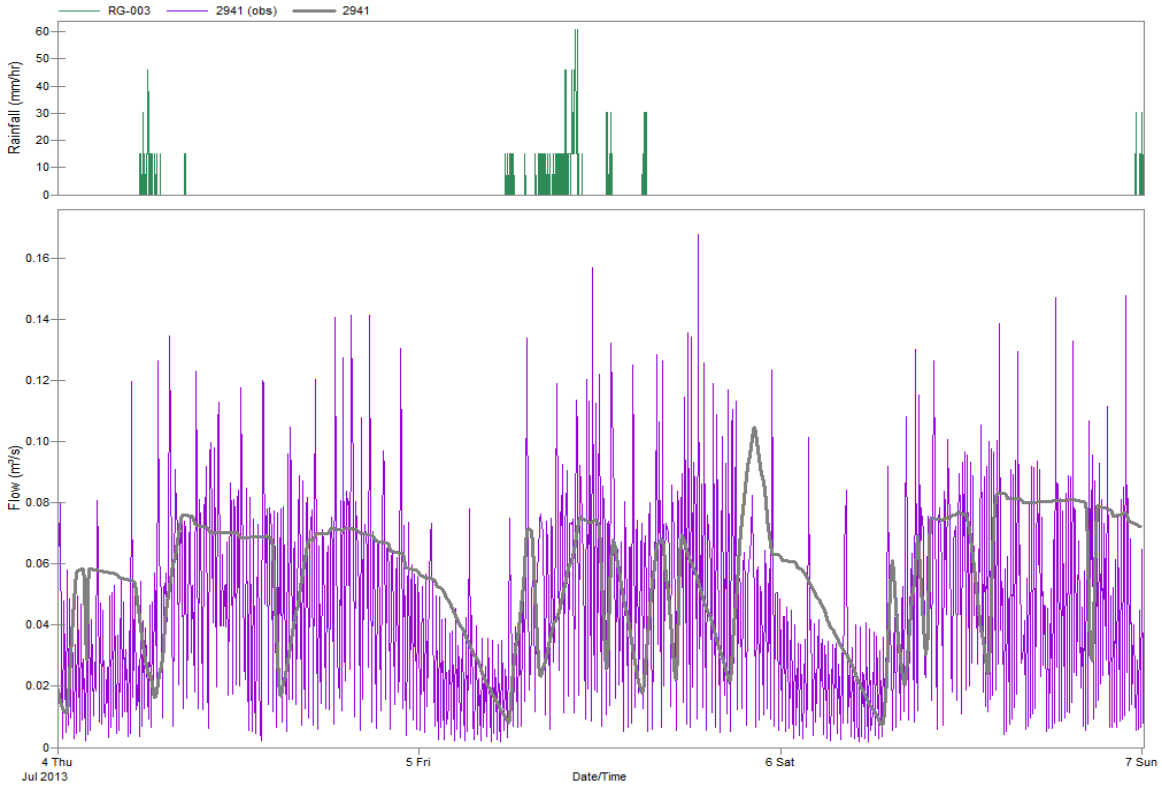
Monitor: FM-005 LEX-8A

Conduit: 2941

Diameter: 825 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m³/s)	Current Max (m³/s)	Observed Mean (m³/s)	Current Mean (m³/s)	Observed Total (m³)	Current Total (m³)
7/3/2013 23:57	72.24	42.4	109.2	0.168	0.105	0.046	0.055	11940	14330
Difference (%)					-38%		20%		20%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

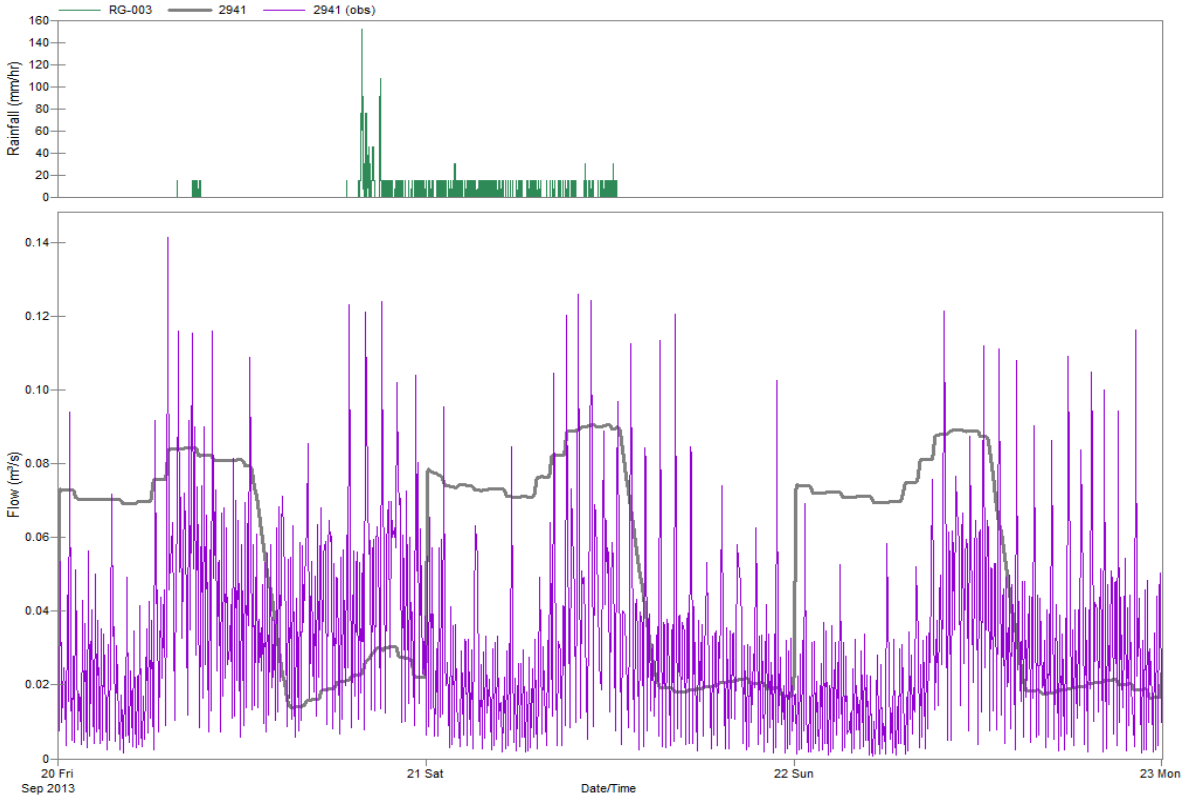
Monitor: FM-005 LEX-8A

Conduit: 2941

Diameter: 825 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m³/s)	Current Max (m³/s)	Observed Mean (m³/s)	Current Mean (m³/s)	Observed Total (m³)	Current Total (m³)
9/19/2013 23:57	72	89.9	164.4	0.141	0.091	0.033	0.053	8444	13830
Difference (%)					-36%		64%		64%



1611-11191: Waterloo Sanitary Master Plan
Dry Weather Calibration - Final

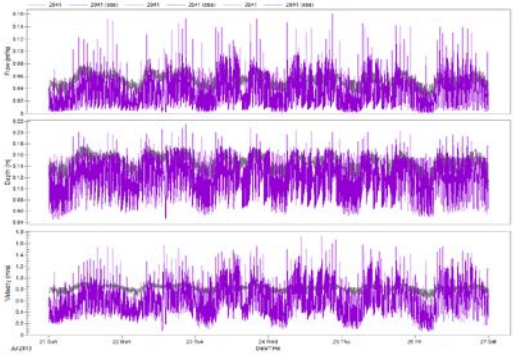
Monitor: FM-005 LEX-8A
Conduit: 2941

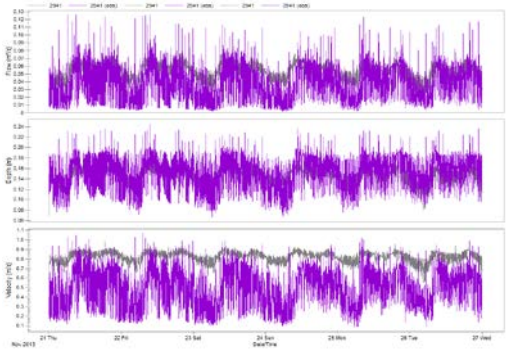
Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	July 21-26, 2013				November 21-26, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	N/A[1]	0.033			N/A[1]	0.033		
	9.41[2]				9.41[2]			
Base Flow (L/s)		0.42[4]				0.42[4]		
Population	N/A[1]	667[4]			N/A[1]	667[4]		
Per Capita (L/c/d)	N/A[1]	100[4]			N/A[1]	100[4]		
Avg. Sewage (L/s)	32.0[2]	13.7[4]			32.0[2]	13.7[4]		
External Flow (Bridgeport SPS)	N/A (included in above Avg. Sewage)	39[3]			N/A (included in above Avg. Sewage)	39[3]		
Pipe (mm)	825	825			825	825		
Total Area (ha)	N/A[1]	12.8[4]			N/A[1]	12.8[4]		
Incremental Area (ha)	N/A[1]	12.8[4]			N/A[1]	12.8[4]		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Sim**	**Diff**	**%**
D_{min} (m)	0.046	0.068	0.023	49%	0.067	0.070	0.003	5%
D_{max} (m)	0.214	0.189	-0.026	-12%	0.245	0.189	-0.057	-23%
Q_{min} (m^3/s)	0.001	0.011	0.010	1078%	0.002	0.011	0.009	393%
Q_{max} (m^3/s)	0.160	0.089	-0.071	-44%	0.126	0.089	-0.037	-29%
Vol (m^3)	19937	27634	7697	39%	20558	27634	7076	34%
Vel_{min} (m/s)	0.1	0.5	0.4	617%	0.1	0.5	0.4	466%
Vel_{max} (m/s)	1.7	1.0	-0.8	-44%	1.1	1.0	-0.1	-9%

Note 1: Information not available. Population and drainage area specific to the Kitchener area serviced by the Bridgeport SPS is unknown.
Note 2: Based on flow monitoring data for the entire subcatchment area, including Kitchener/Waterloo areas flowing to the Bridgeport SPS and Waterloo areas in Waterloo flowing by gravity.
Note 3: Total Flow including DWF sewage generation and GWI
Note 4: Parameters for Waterloo area that drains by gravity upstream of the flow monitor. Excludes the Bridgeport SPS catchment area, which is already respresented as an external flow.

Graph





1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-006 LRL-56

Conduit: 4379

Diameter: 750 mm

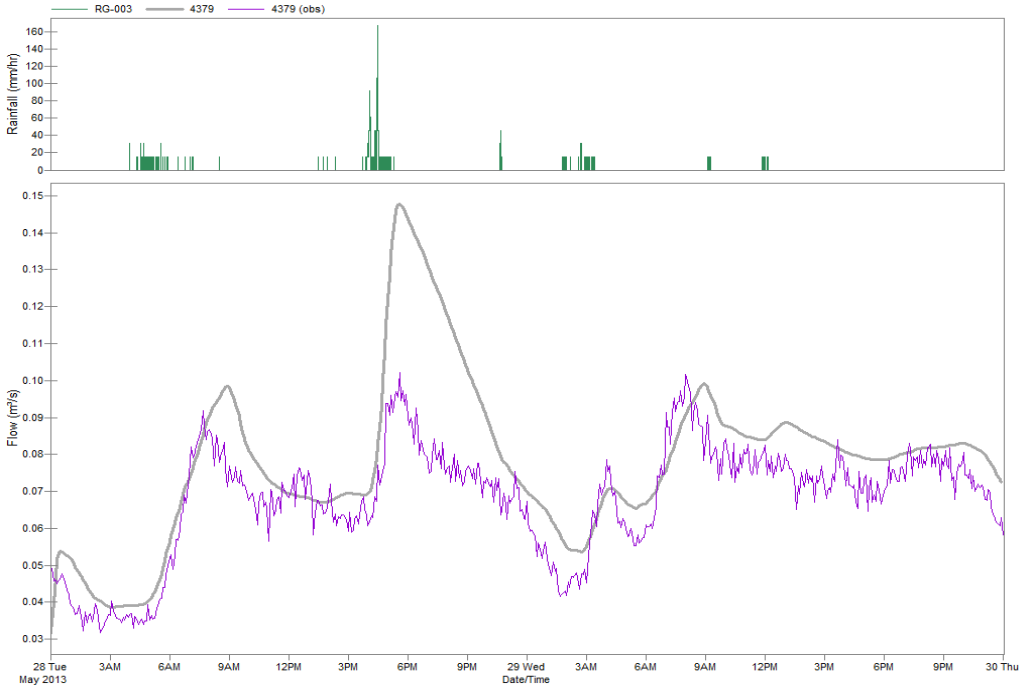
Model Input Parameters

Parameter	1	2	3
R	0.012	0.018	0.007
T	0.20	12.00	24.00
K	30	10	4

R_{total} 3.7%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/27/2013 23:59	48.04	41.9	109.2	0.102	0.148	0.068	0.078	11740	13470
Difference (%)					45%		15%		15%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

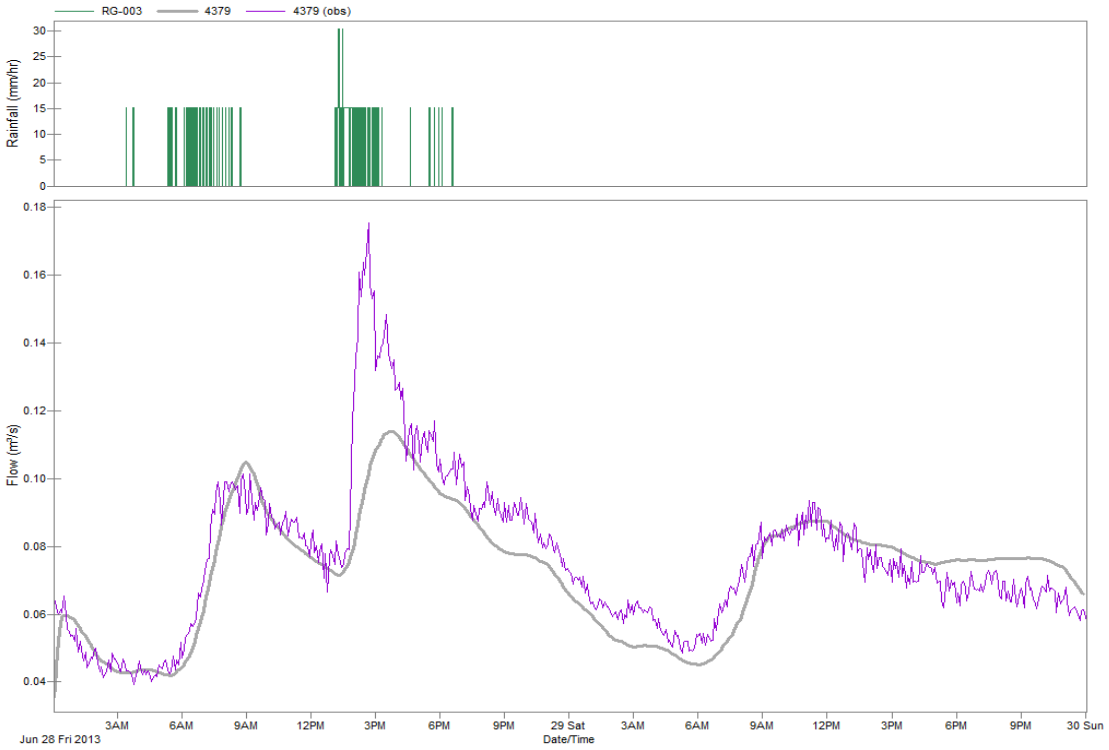
Monitor: FM-006 LRL-56

Conduit: 4379

Diameter: 750 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:01	48.02	31.6	39.6	0.175	0.114	0.076	0.073	13210	12540
Difference (%)					-35%		-5%		-5%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

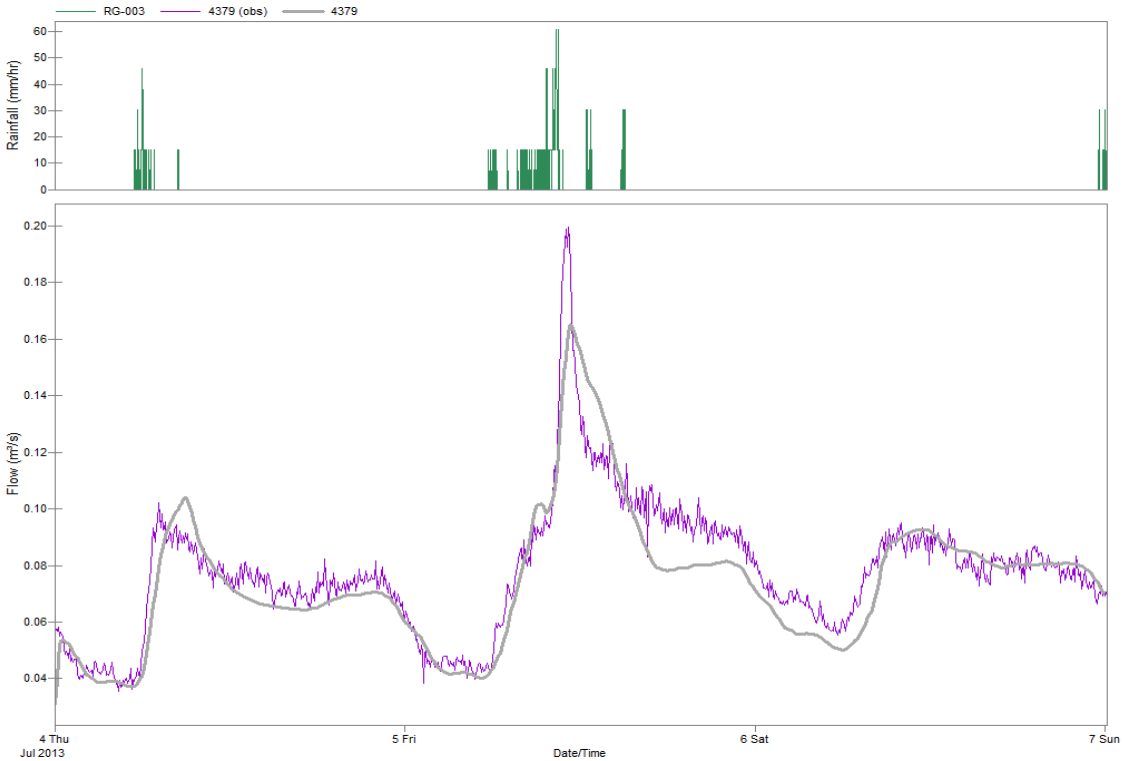
Monitor: FM-006 LRL-56

Conduit: 4379

Diameter: 750 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:57	72.24	42.4	109.2	0.200	0.165	0.078	0.074	20200	19240
Difference (%)					-17%		-4%		-5%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-006 LRL-56

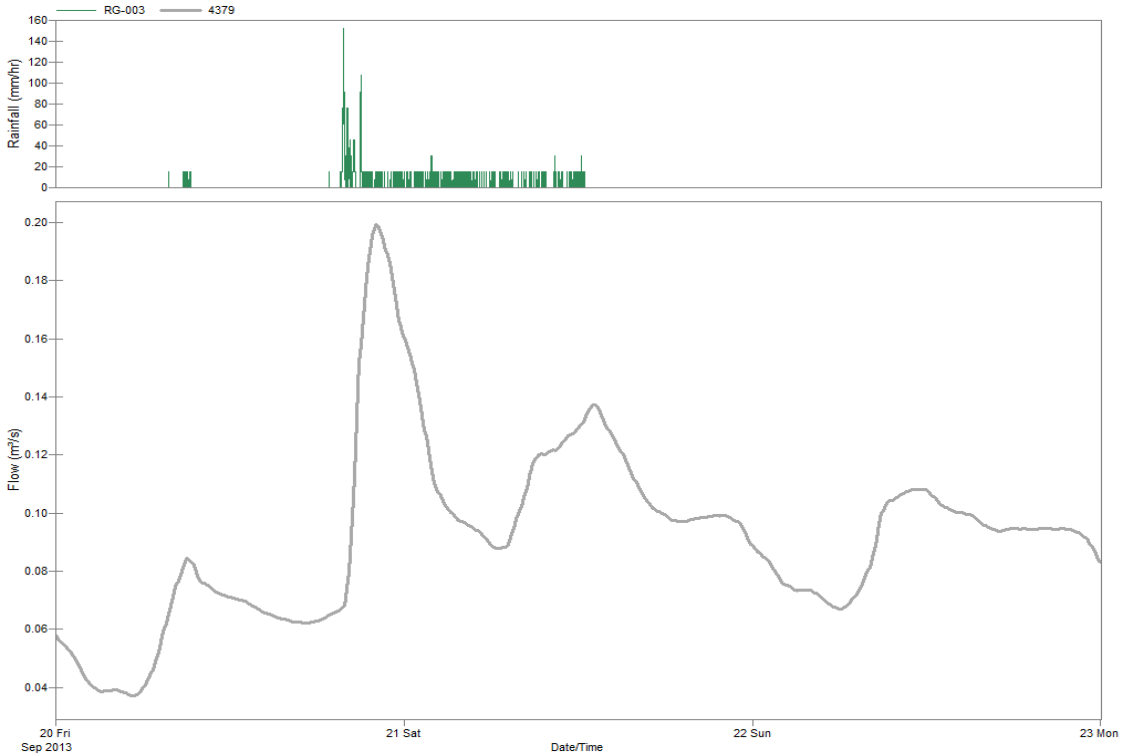
Conduit: 4379

Diameter: 750 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Note: Flow monitoring data is not avaialble for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
9/19/2013 23:57	72	89.9	164.4	N/A	0.199	N/A	0.092	N/A	23920
Difference (%)					N/A		N/A		N/A



1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

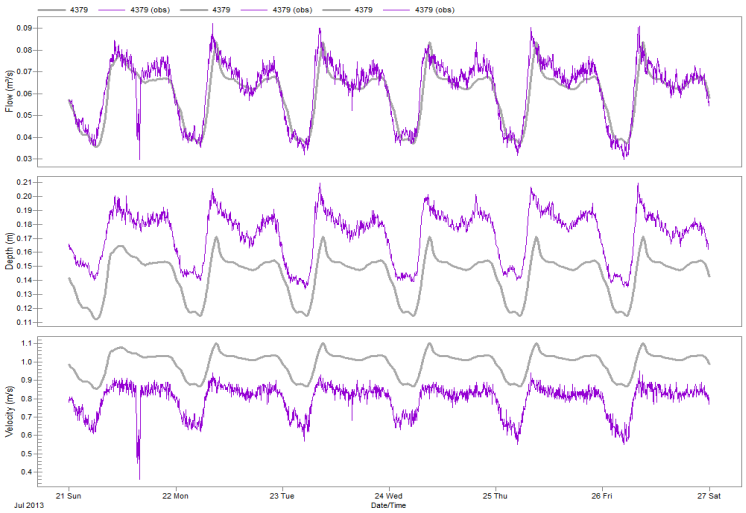
Monitor: FM-006 LRL-56

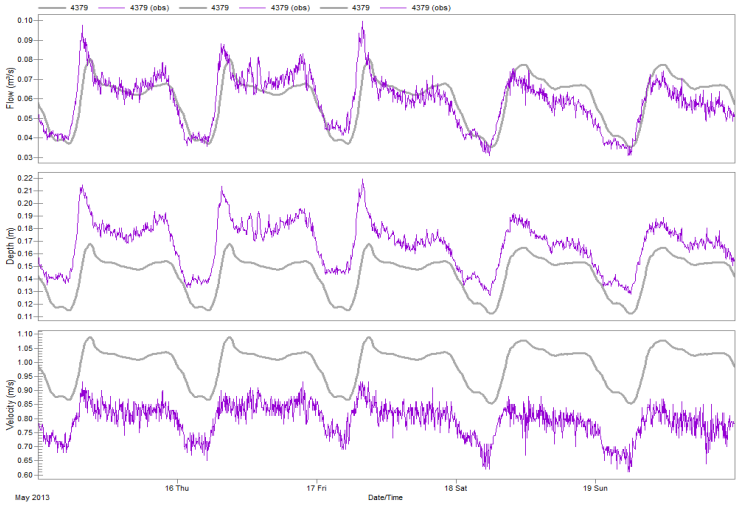
Conduit: 4379

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	July 21-26, 2013				May 15-19, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.051	0.044			0.051	0.044		
Base Flow (L/s)	17.98	15.59			17.98	15.59		
Population	15708	15441			15708	15441		
Per Capita (L/c/d)	194	194			194	194		
Avg. Sewage (L/s)	35.2	34.6			35.2	34.6		
Pipe (mm)	750	750			750	750		
Total Area (ha)	406.8	404.5			406.8	404.5		
Incremental Area (ha)	352.9	352.9			352.9	352.9		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.210	0.171	-0.039	-18%	0.220	0.171	-0.049	-22%
Q_{max} (m^3/s)	0.092	0.084	-0.009	-10%	0.100	0.084	-0.016	-16%
Vol (m^3)	32142	30964	-1178	-4%	25467	25813	345	1%
Vel_{max} (m/s)	1.0	1.1	0.2	16%	0.9	1.1	0.2	19%

Graph





1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-007 LWD-6

Conduit: 5211

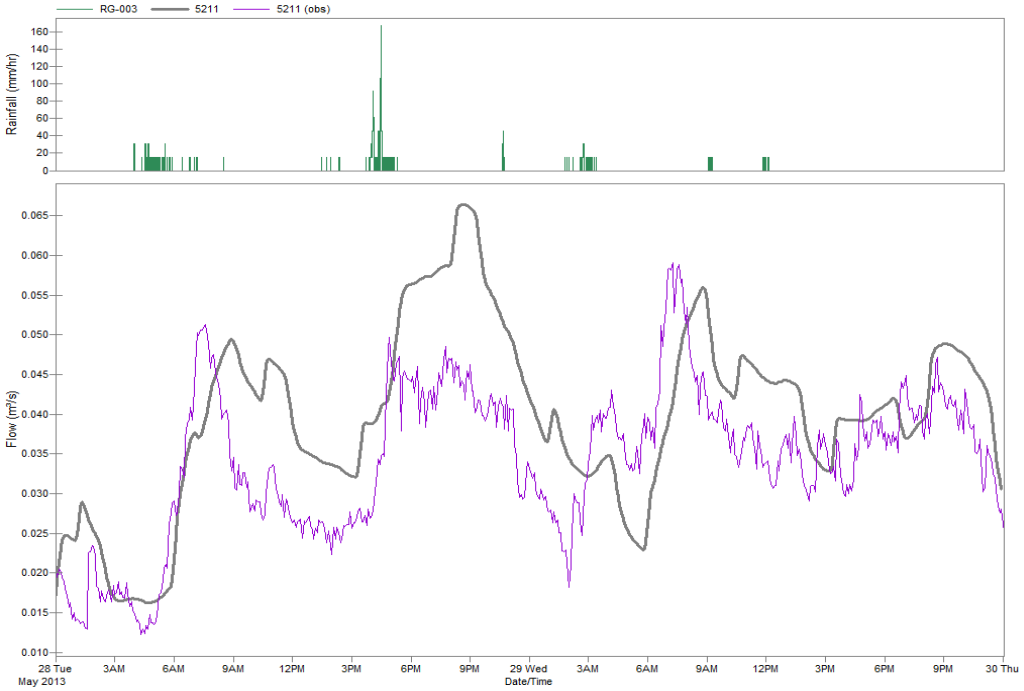
Diameter: 750 mm

Model Input Parameters

Parameter	1	2	3	R_{total}
R	0.008	0.001	0.001	1.0%
T	0.35	12.00	24.00	
K	35	5	4	

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/27/2013 23:59	48.04	41.9	109.2	0.059	0.066	0.034	0.040	5912	6859
Difference (%)					12%		16%		16%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

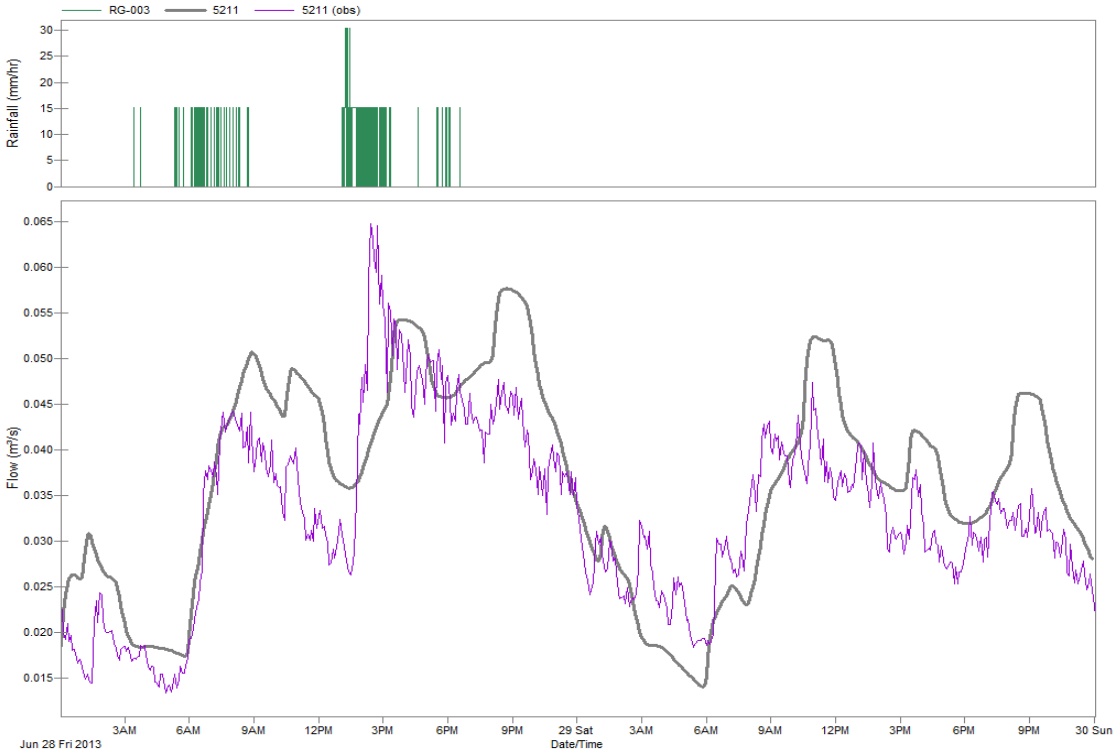
Monitor: FM-007 LWD-6

Conduit: 5211

Diameter: 750 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:01	48.02	31.6	39.6	0.065	0.058	0.033	0.036	5700	6285
Difference (%)					-11%		11%		10%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-007 LWD-6

Conduit: 5211

Diameter: 750 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:57	72.24	42.4	109.2	0.072	0.071	0.033	0.038	8549	9813
Difference (%)					-2%		15%		15%

1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

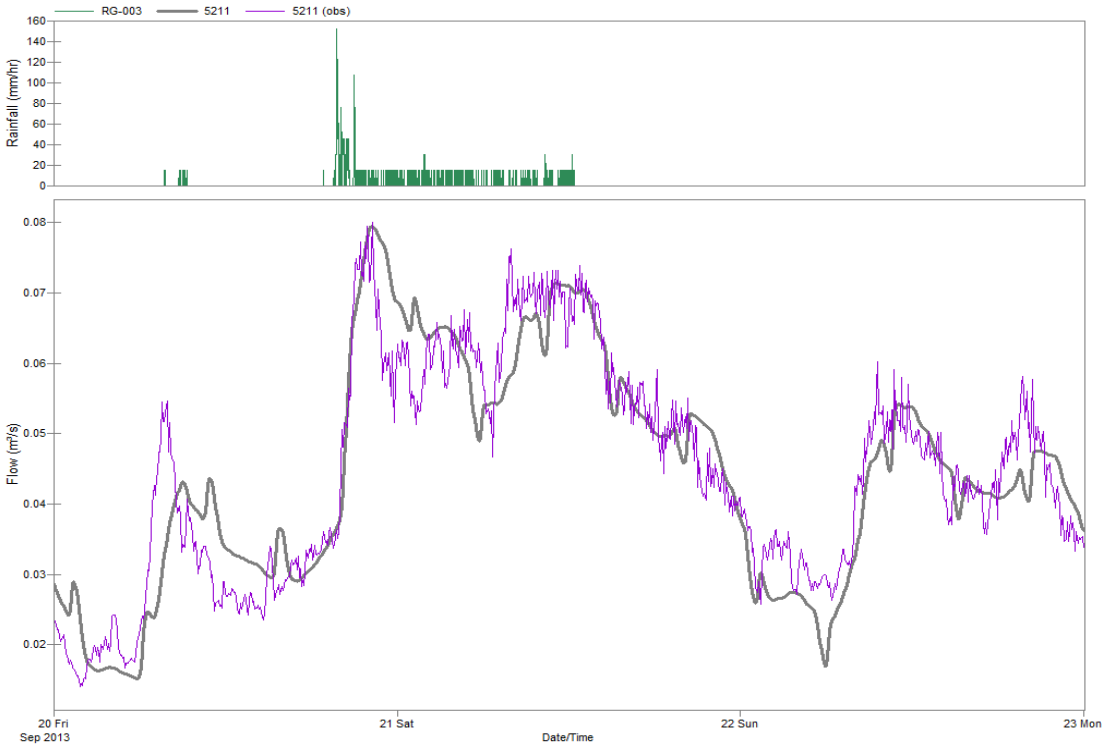
Monitor: FM-007 LWD-6

Conduit: 5211

Diameter: 750 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m³/s)	Current Max (m³/s)	Observed Mean (m³/s)	Current Mean (m³/s)	Observed Total (m³)	Current Total (m³)
9/19/2013 23:58	72	89.9	164.4	0.080	0.079	0.045	0.044	11570	11510
Difference (%)					-1%		-1%		-1%



1611-11191: Waterloo Sanitary Master Plan

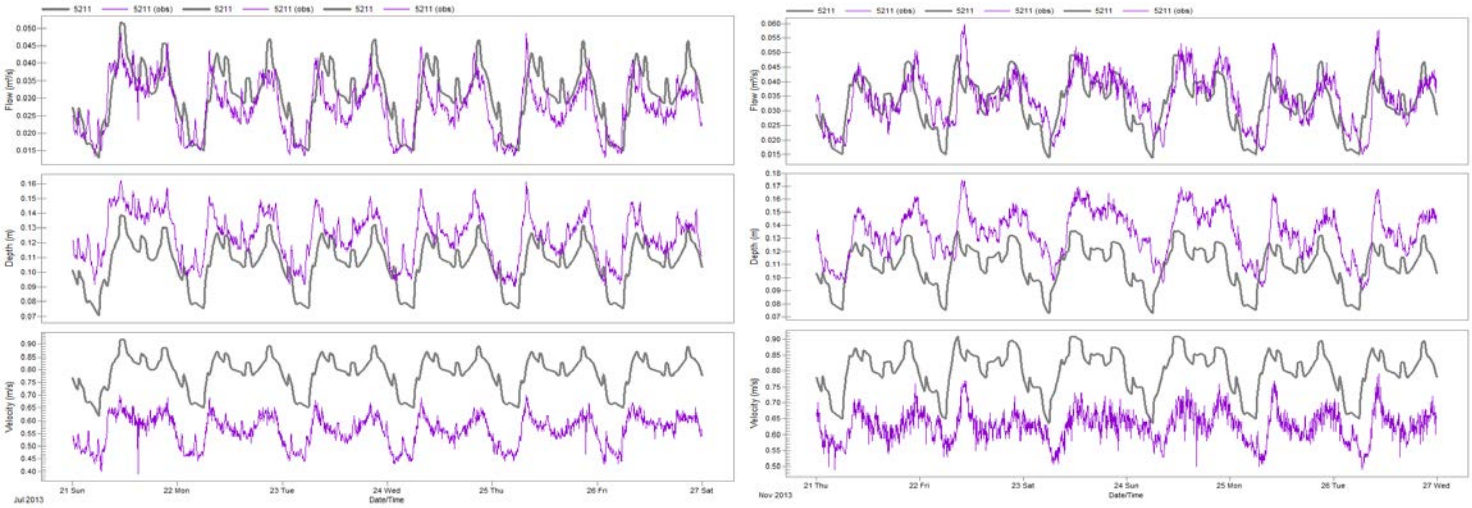
Dry Weather Calibration - Final

Monitor:	FM-007	LWD-6
Conduit:	5211	

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	July 21-26, 2013				November 21-26, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.018	0.018			0.018	0.018		
Base Flow (L/s)	4.69	4.65			4.69	4.65		
Population	10600	10568			10600	10568		
Per Capita (L/c/d)	121	121			121	121		
Avg. Sewage (L/s)	14.8	14.8			14.8	14.8		
Pipe (mm)	750	750			750	750		
Total Area (ha)	259.3	257.1			259.3	257.1		
Incremental Area (ha)	259.3	257.1			259.3	257.1		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.162	0.139	-0.024	-15%	0.174	0.135	-0.039	-22%
Q_{max} (m^3/s)	0.049	0.052	0.003	6%	0.060	0.049	-0.011	-18%
Vol (m^3)	14263	16054	1791	13%	17652	16949	-704	-4%
Vel_{max} (m/s)	0.7	0.9	0.2	31%	0.8	0.9	0.1	15%

Graph



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-008 KEA-30

Conduit: 5462

Diameter: 250 mm

Model Input Parameters

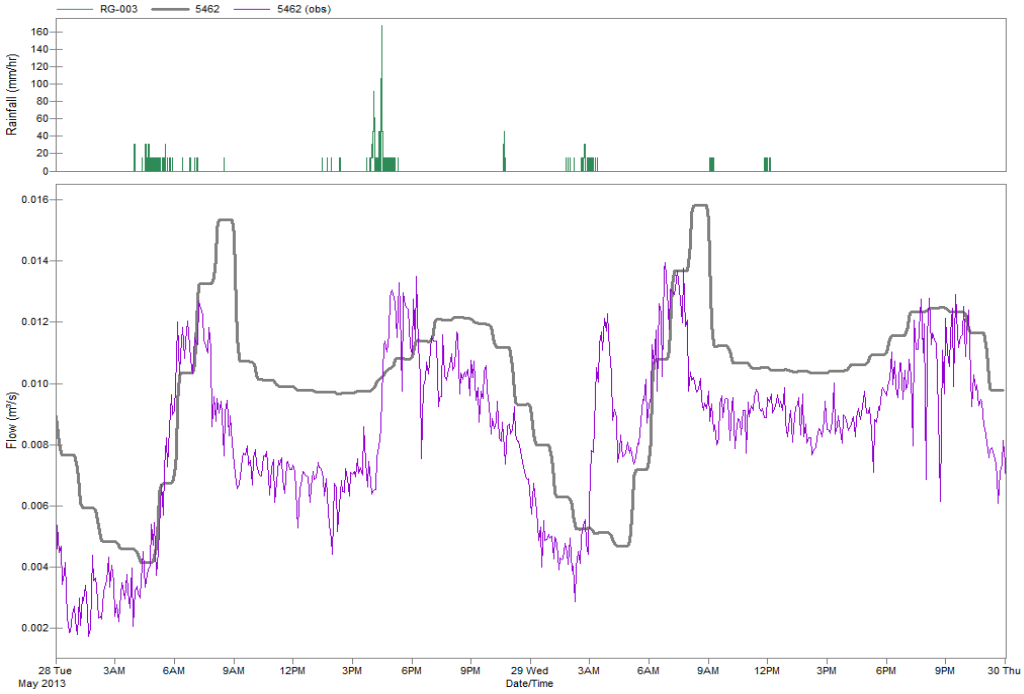
Parameter	1	2	3
R	0.001	0.005	0.007
T	0.20	20.52	24.00
K	33	20	4

R_{total}

1.3%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/27/2013 23:59	48.04	41.9	109.2	0.014	0.016	0.008	0.010	1436	1705
Difference (%)					13%		19%		19%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

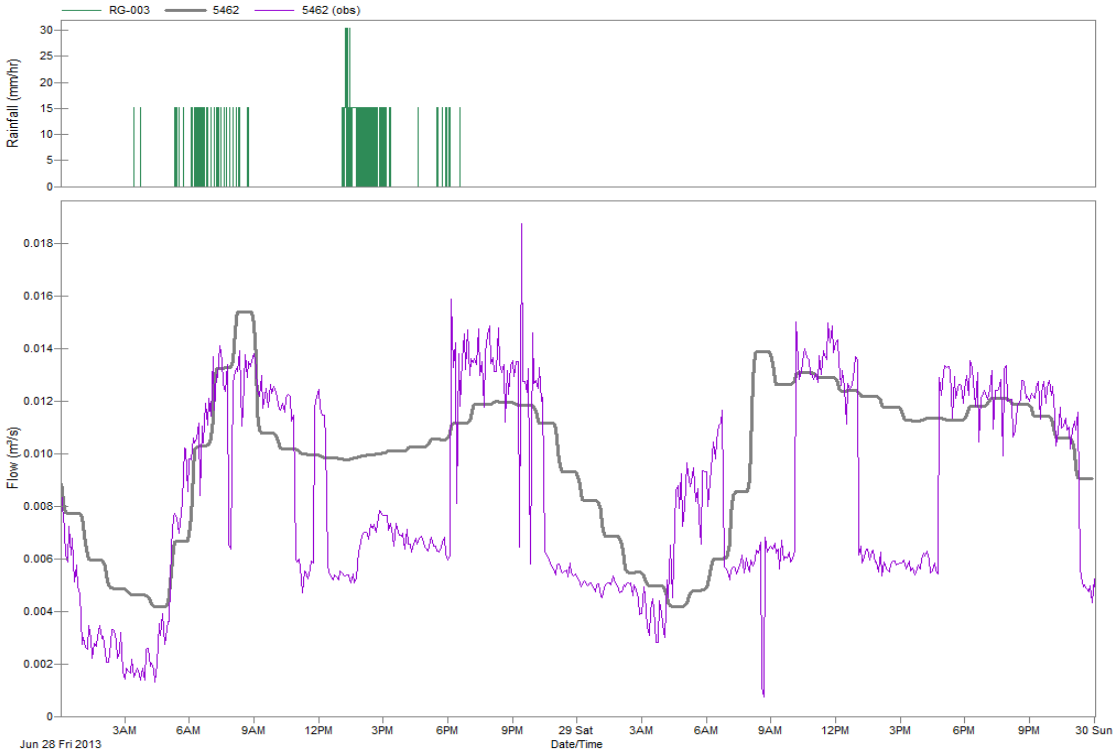
Monitor: FM-008 KEA-30

Conduit: 5462

Diameter: 250 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:01	48.02	31.6	39.6	0.019	0.015	0.008	0.010	1442	1689
Difference (%)					-18%		18%		17%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-008 KEA-30

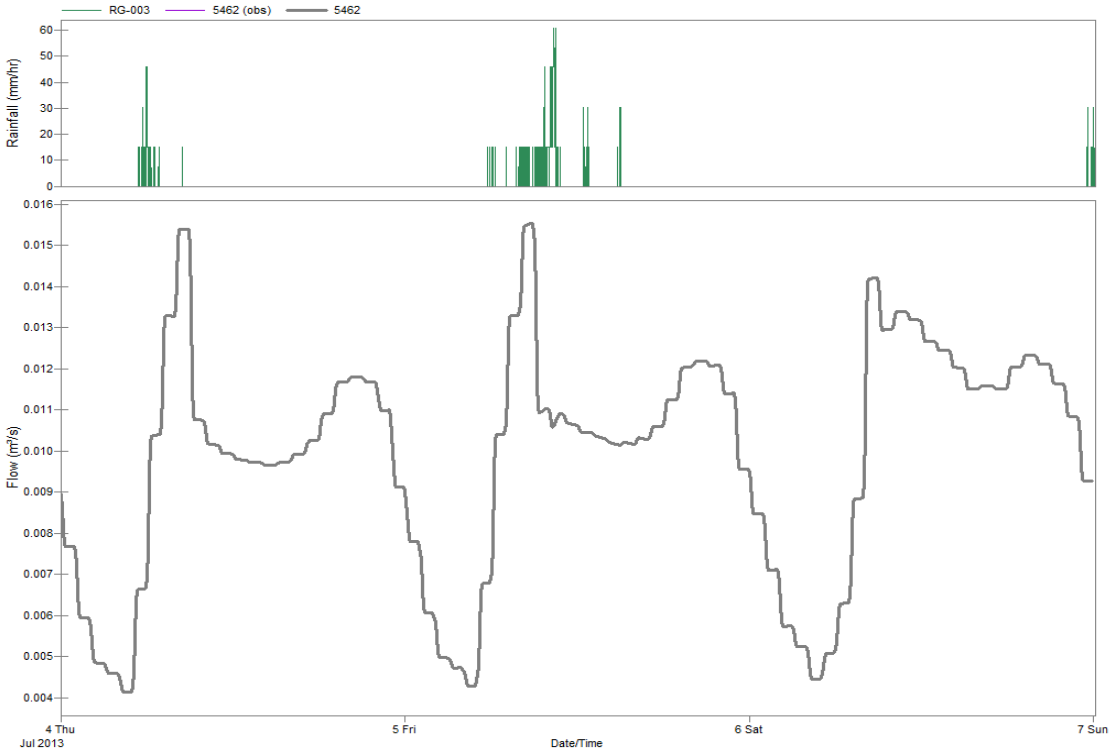
Conduit: 5462

Diameter: 250 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Note: Flow monitoring data is not available for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:57	72.24	42.4	109.2	N/A	0.016	N/A	0.010	N/A	2556
Difference (%)					N/A		N/A		N/A



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

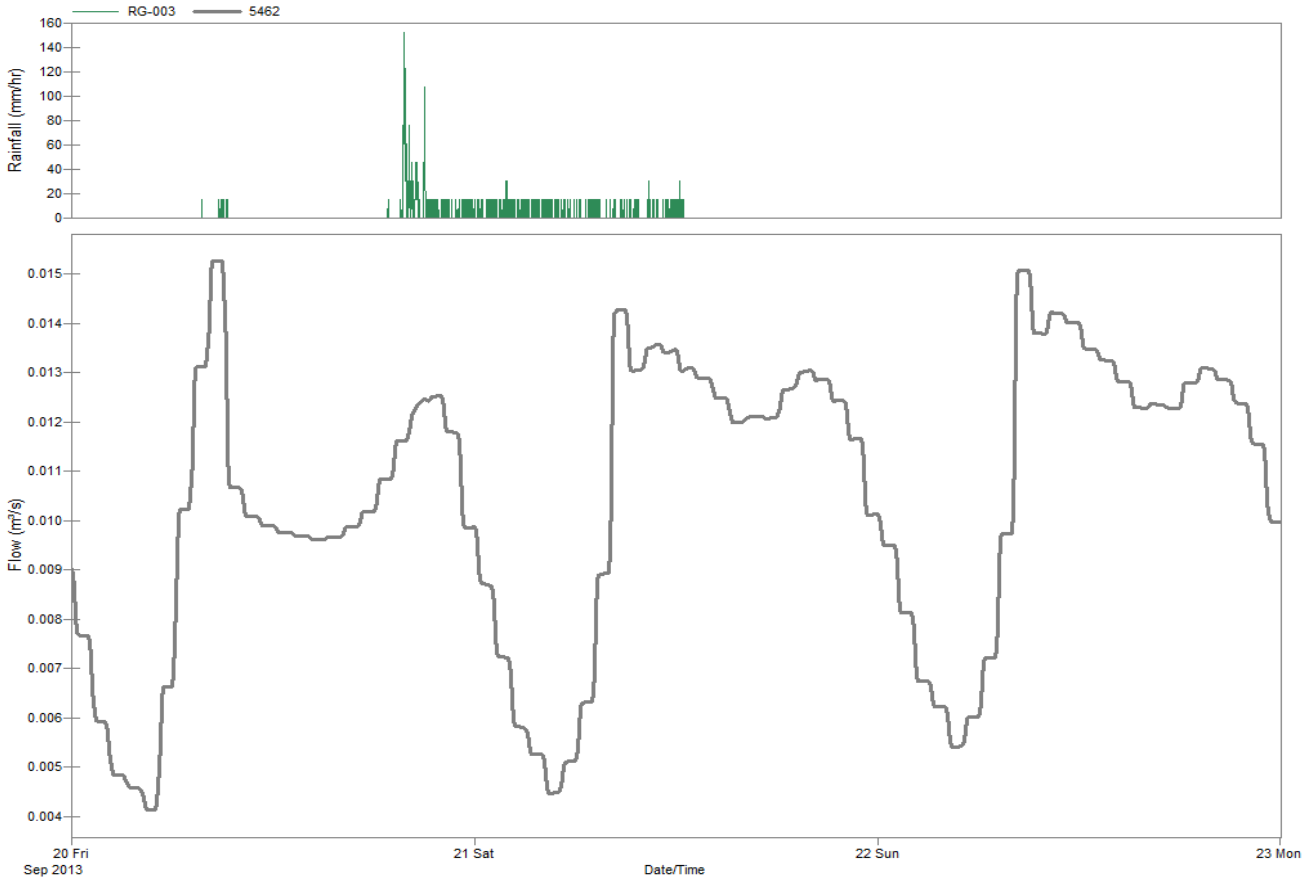
Monitor: FM-008 KEA-30

Conduit: 5462

Diameter: 250 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m³/s)	Current Max (m³/s)	Observed Mean (m³/s)	Current Mean (m³/s)	Observed Total (m³)	Current Total (m³)
9/19/2013 23:57	72	89.9	164.4	N/A	0.015	N/A	0.010	N/A	2697
Difference (%)					N/A		N/A		N/A



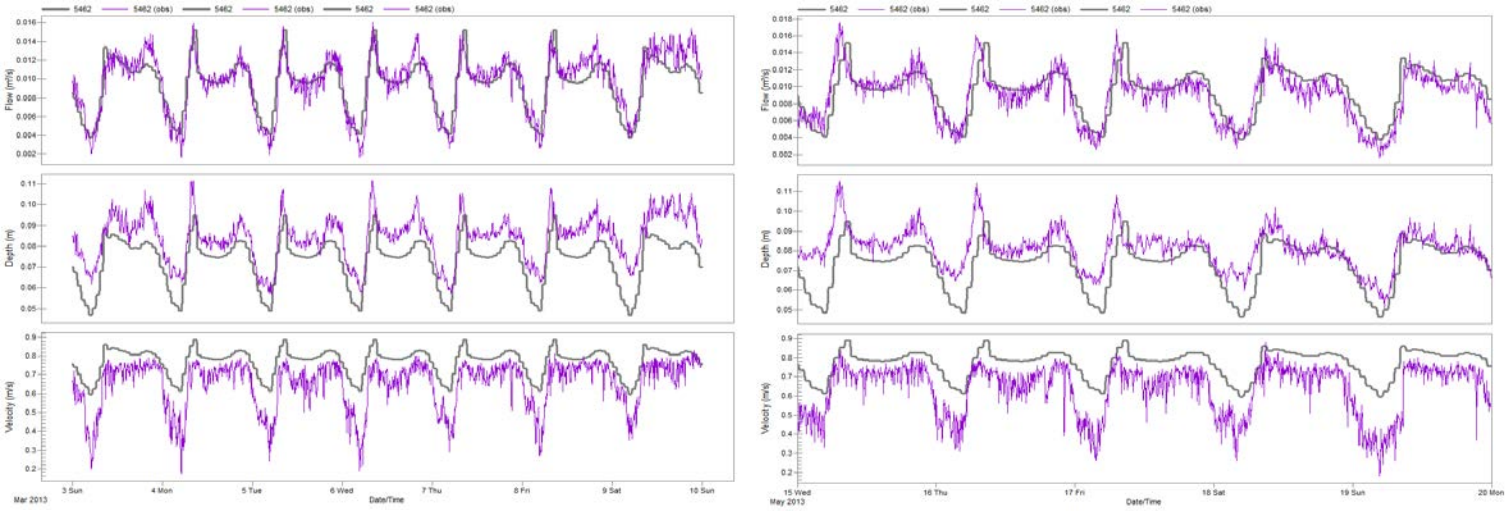
1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

			Target %	
Monitor:	FM-008	KEA-30	D_{max}	-20 to +20%
Conduit:	5462		Q_{max}	-15 to +15%
			Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	March 3-9, 2013				May 15-19, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.059	0.059			0.059	0.059		
Base Flow (L/s)	3.17	3.03			3.17	3.03		
Population	2672	2642			2672	2642		
Per Capita (L/c/d)	209	211			209	211		
Avg. Sewage (L/s)	6.4	6.4			6.4	6.4		
Pipe (mm)	250	250			250	250		
Total Area (ha)	53.9	51.7			53.9	51.7		
Incremental Area (ha)	53.9	51.7			53.9	51.7		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.112	0.095	-0.017	-15%	0.115	0.095	-0.020	-18%
Q_{max} (m^3/s)	0.016	0.015	-0.001	-5%	0.018	0.015	-0.002	-13%
Vol (m^3)	5868	5728	-139	-2%	3885	4092	207	5%
Vel_{max} (m/s)	0.8	0.9	0.1	7%	0.9	0.9	0.0	1%

Graph



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-009 MPL-63

Conduit: 2951

Diameter: 300 mm

Model Input Parameters

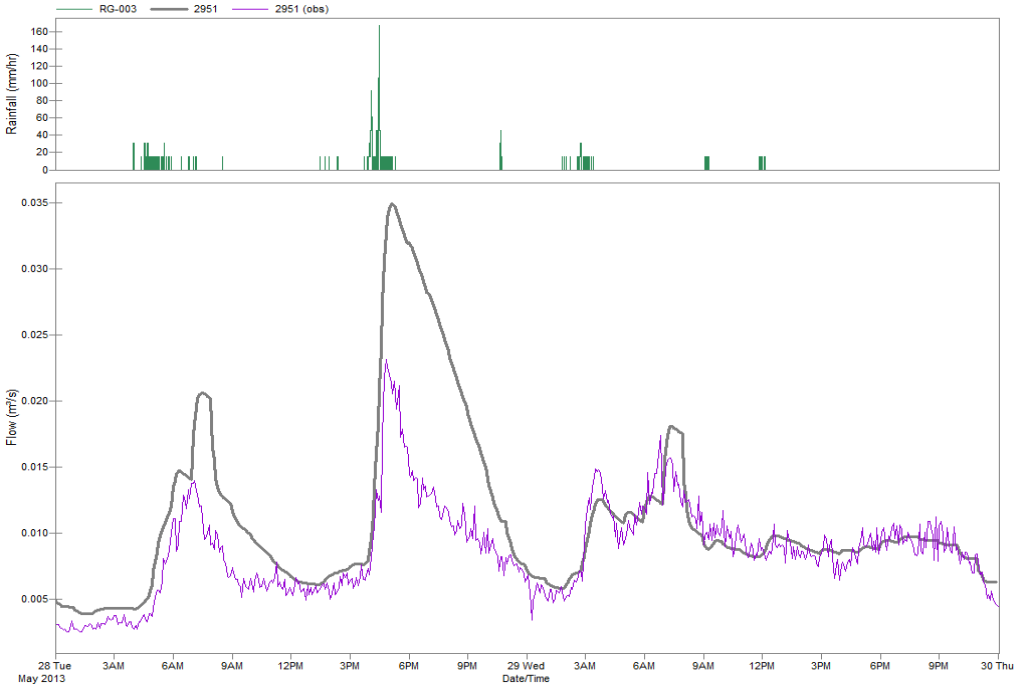
Parameter	1	2	3
R	0.020	0.005	0.001
T	0.28	12.00	24.00
K	24	5	4

R_{total}

2.6%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/27/2013 23:59	48.04	41.9	109.2	0.023	0.035	0.009	0.011	1505	1912
Difference (%)					51%		27%		27%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

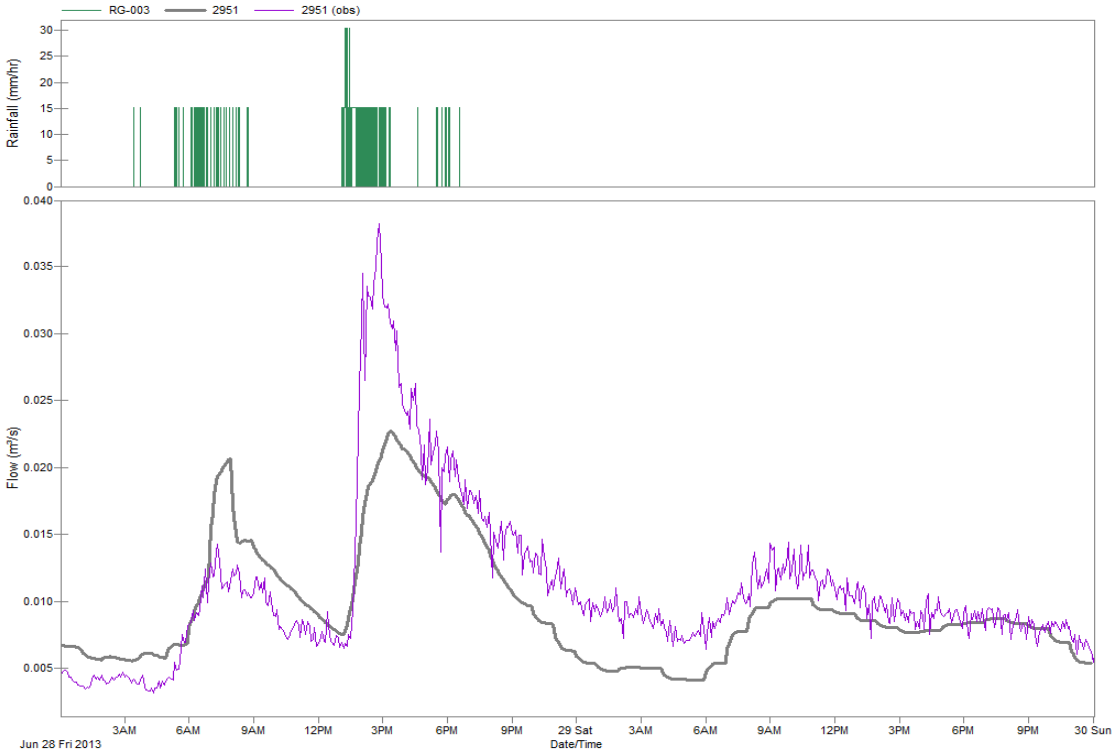
Monitor: FM-009 MPL-63

Conduit: 2951

Diameter: 300 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:01	48.02	31.6	39.6	0.038	0.023	0.011	0.010	1887	1648
Difference (%)					-41%		-12%		-13%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

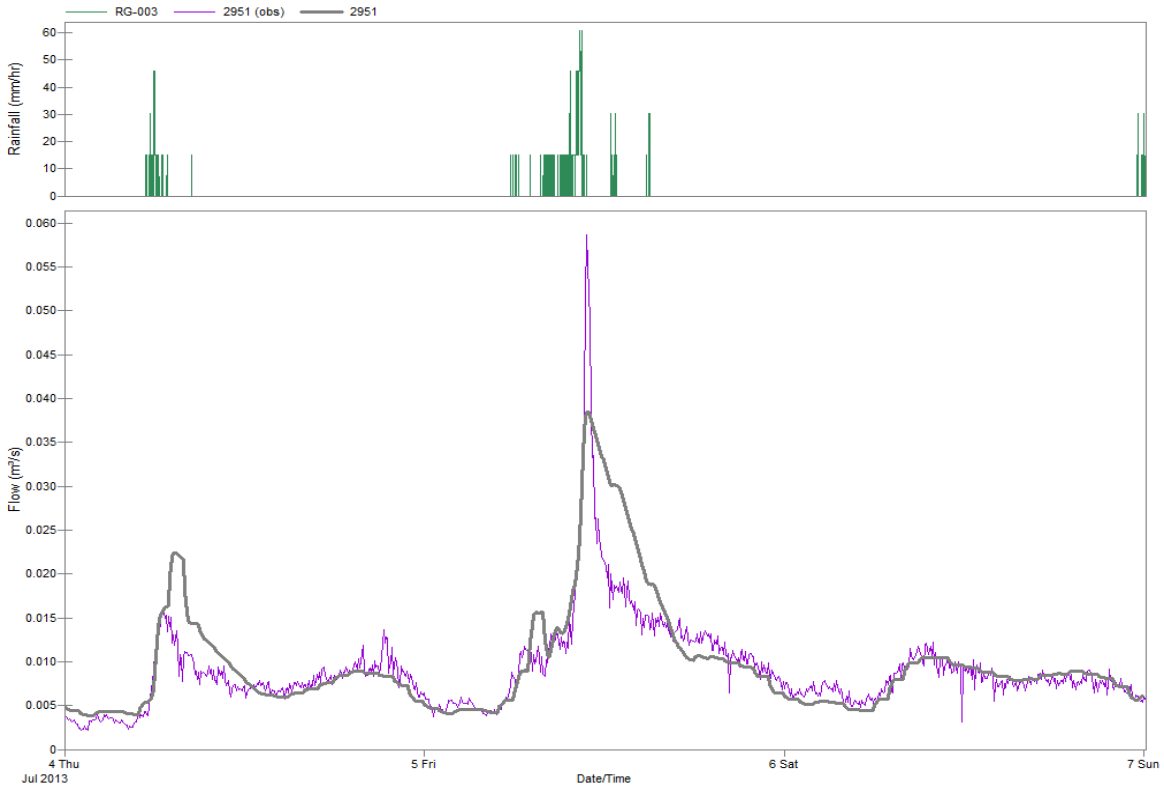
Monitor: FM-009 MPL-63

Conduit: 2951

Diameter: 300 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:57	72.24	42.4	109.2	0.059	0.038	0.009	0.010	2366	2518
Difference (%)					-34%		7%		6%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-009 MPL-63

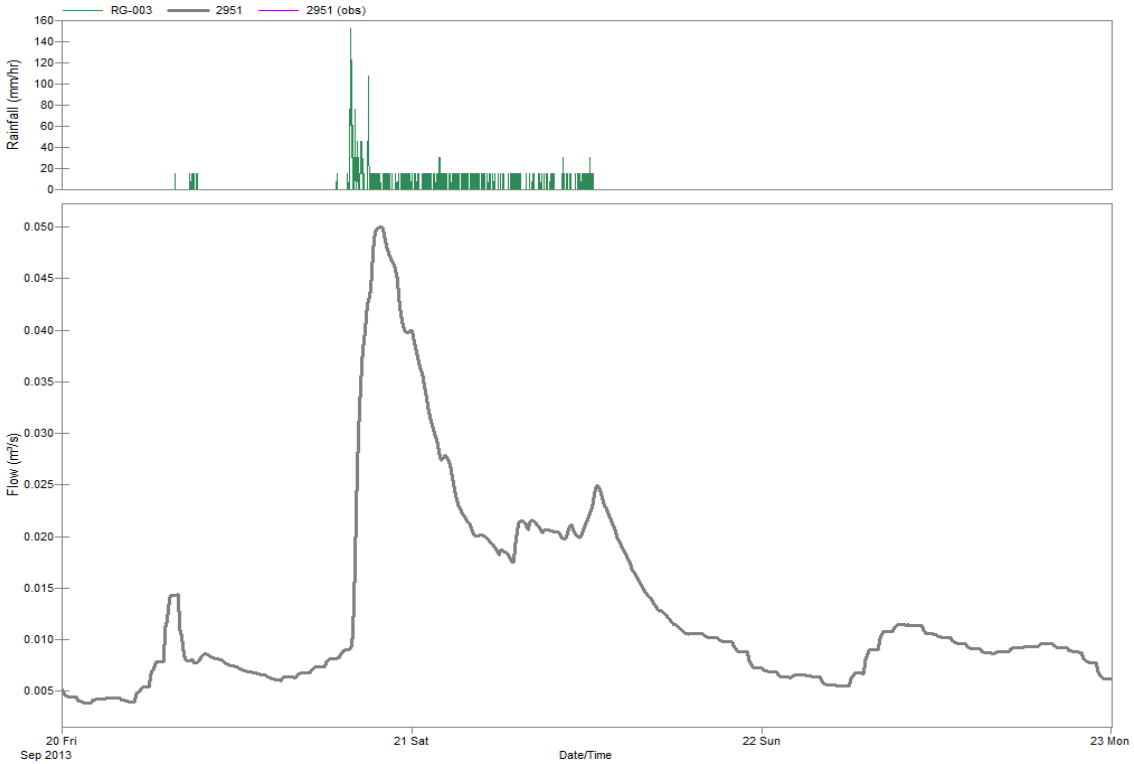
Conduit: 2951

Diameter: 300 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Note: Flow monitoring data is not available for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
9/19/2013 23:57	72	89.9	164.4	N/A	0.050	N/A	0.013	N/A	3430
Difference (%)					N/A		N/A		N/A



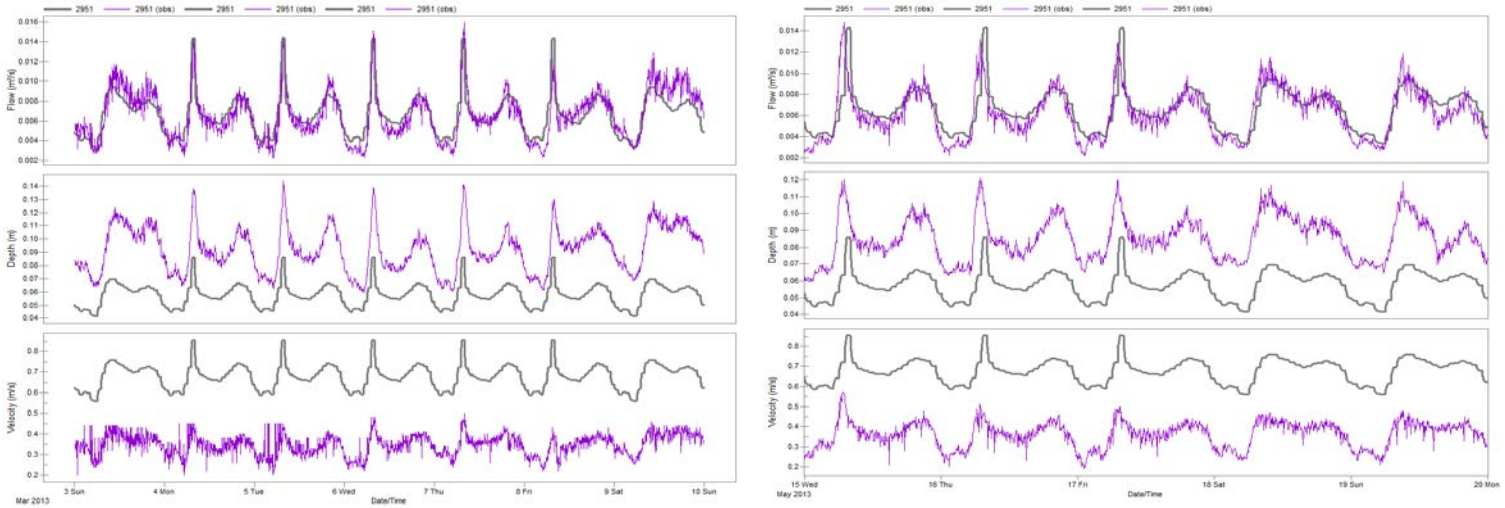
1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

			Target %	
Monitor:	FM-009	MPL-63	D_{max}	-20 to +20%
Conduit:	2951		Q_{max}	-15 to +15%
			Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	March 3-9, 2013				May 15-19, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.031	0.032			0.031	0.032		
Base Flow (L/s)	2.42	2.42			2.42	2.42		
Population	3296	3294			3296	3294		
Per Capita (L/c/d)	94	110			94	110		
Avg. Sewage (L/s)	3.6	4.20			3.6	4.20		
Pipe (mm)	300	300			300	300		
Total Area (ha)	78.6	76.8			78.6	76.8		
Incremental Area (ha)	78.6	76.8			78.6	76.8		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.144	0.086	-0.058	-40%	0.121	0.086	-0.035	-29%
Q_{max} (m^3/s)	0.016	0.014	-0.002	-10%	0.015	0.014	-0.001	-4%
Vol (m^3)	3996	4003	8	0%	2662	2860	198	7%
Vel_{max} (m/s)	0.5	0.9	0.4	71%	0.6	0.9	0.3	50%

Graph



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-010 L31-3

Conduit: 1264

Diameter: 250

Model Input Parameters

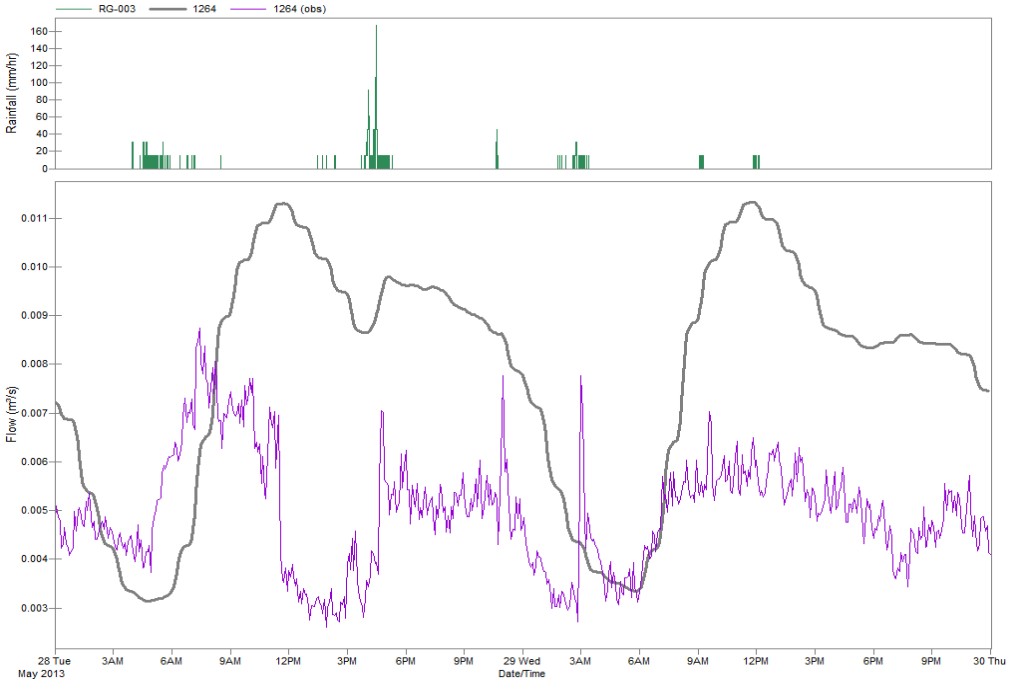
Parameter	1	2	3
R	0.001	0.001	0.001
T	0.27	12.00	24.00
K	75	5	4

R_{total}

0.3%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/27/2013 23:59	48.04	41.9	109.2	0.009	0.011	0.005	0.008	857	1350
Difference (%)					30%		58%		58%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-010 L31-3

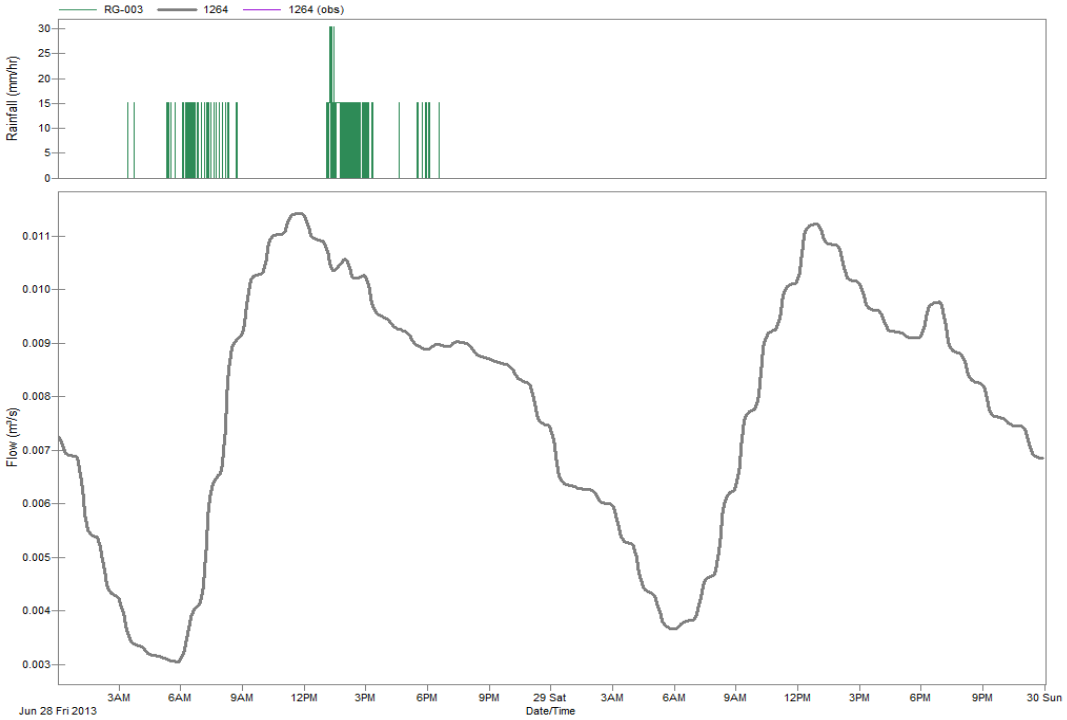
Conduit: 1264

Diameter: 250

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Note: Flow monitoring data is not available for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:01	48.02	31.6	39.6	N/A	0.011	N/A	0.008	N/A	1335
Difference (%)					N/A		N/A		N/A



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-010 L31-3

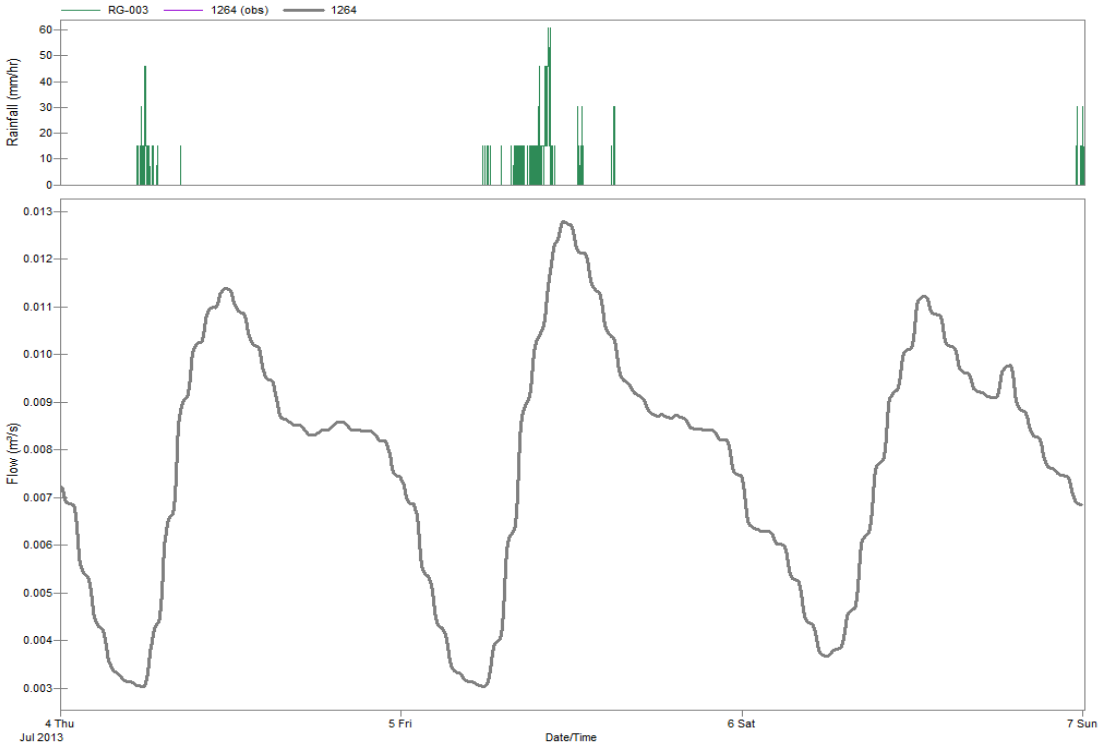
Conduit: 1264

Diameter: 250

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Note: Flow monitoring data is not available for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:57	72.24	42.4	109.2	N/A	0.013	N/A	0.008	N/A	2009
Difference (%)					N/A		N/A		N/A



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-010 L31-3

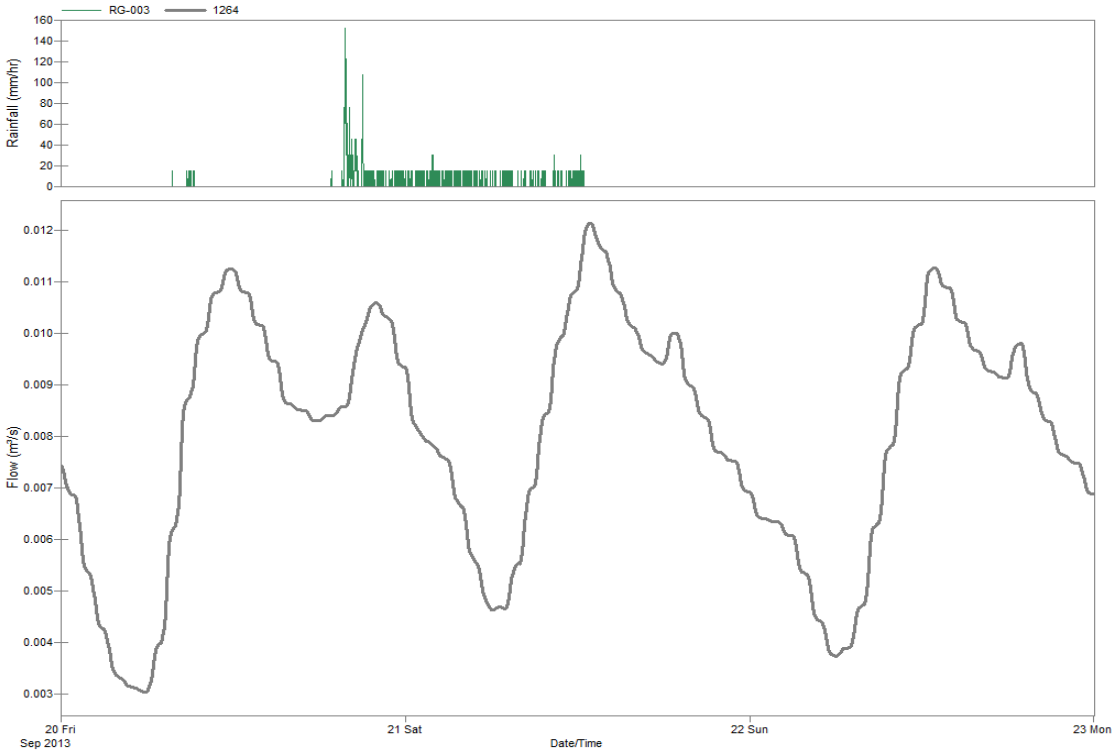
Conduit: 1264

Diameter: 250

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Note: Flow monitoring data is not available for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
9/19/2013 23:57	72	89.9	164.4	N/A	0.012	N/A	0.008	N/A	2067
Difference (%)					N/A		N/A		N/A



1611-11191: Waterloo Sanitary Master Plan

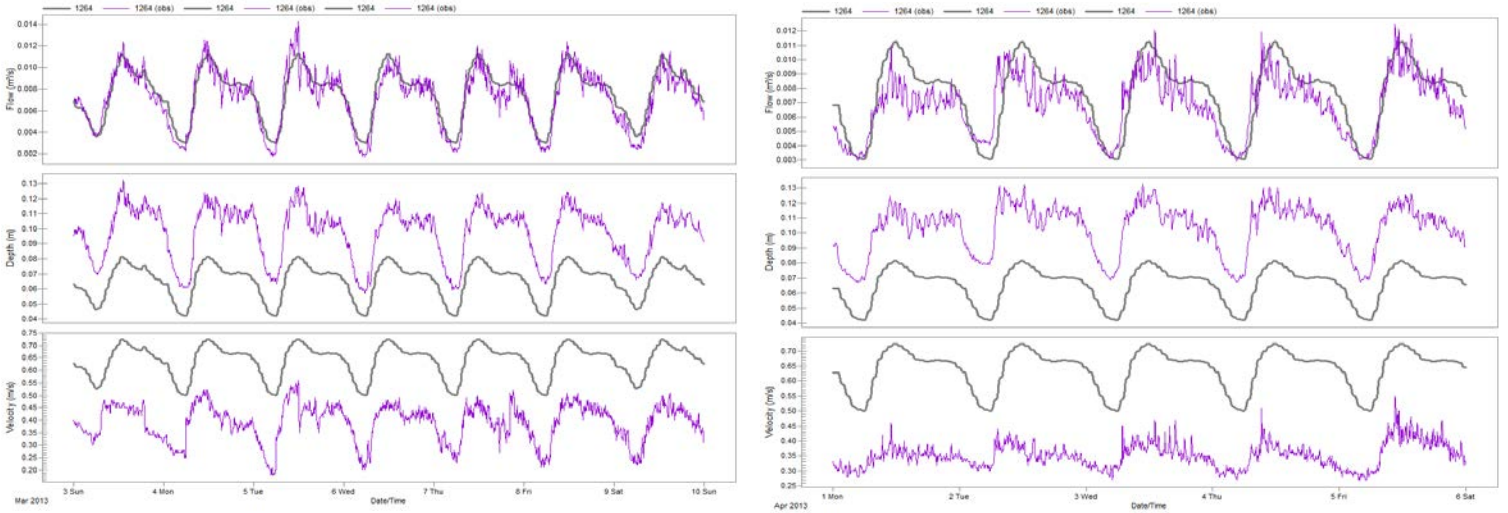
Dry Weather Calibration - Final

Monitor:	FM-010	L31-3
Conduit:	1264	

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	March 3-9, 2013				April 1-5, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.057	0.059			0.057	0.059		
Base Flow (L/s)	2.08	2.11			2.08	2.11		
Population	3204	3191			3204	3191		
Per Capita (L/c/d)	129	176			129	176		
Avg. Sewage (L/s)	4.8	6.5			4.8	6.5		
Pipe (mm)	250	250			250	250		
Total Area (ha)	36.3	35.8			36.3	35.8		
Incremental Area (ha)	36.3	35.8			36.3	35.8		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.132	0.081	-0.051	-38%	0.133	0.081	-0.051	-39%
Q_{max} (m^3/s)	0.014	0.011	-0.003	-21%	0.012	0.011	-0.001	-10%
Vol (m^3)	4367	4590	223	5%	2943	3278	335	11%
Vel_{max} (m/s)	0.6	0.7	0.2	29%	0.6	0.7	0.2	32%

Graph



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-011 UNI-4

Conduit: 3113

Diameter: 600 mm

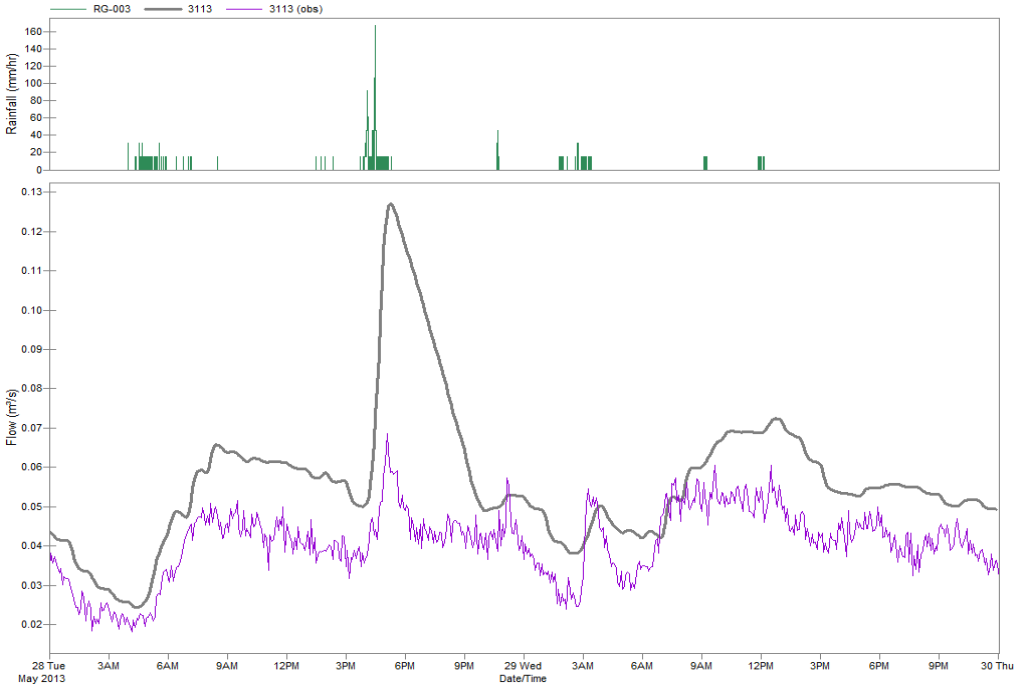
Model Input Parameters

Parameter	1	2	3
R	0.030	0.020	0.001
T	0.25	12.00	24.00
K	20	5	5

R_{total} 5.1%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/27/2013 23:59	48.04	41.9	109.2	0.069	0.127	0.041	0.056	7059	9745
Difference (%)					85%		38%		38%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

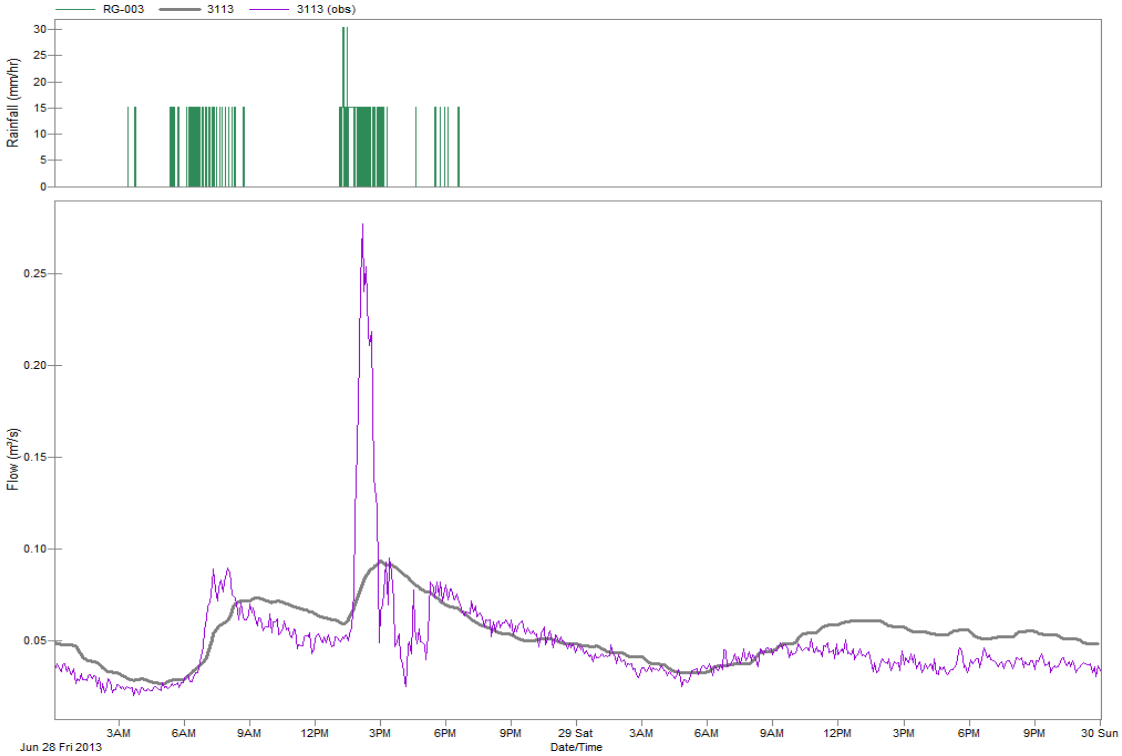
Monitor: FM-011 UNI-4

Conduit: 3113

Diameter: 600 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:01	48.02	31.6	39.6	0.277	0.093	0.048	0.053	8249	9081
Difference (%)					-66%		10%		10%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

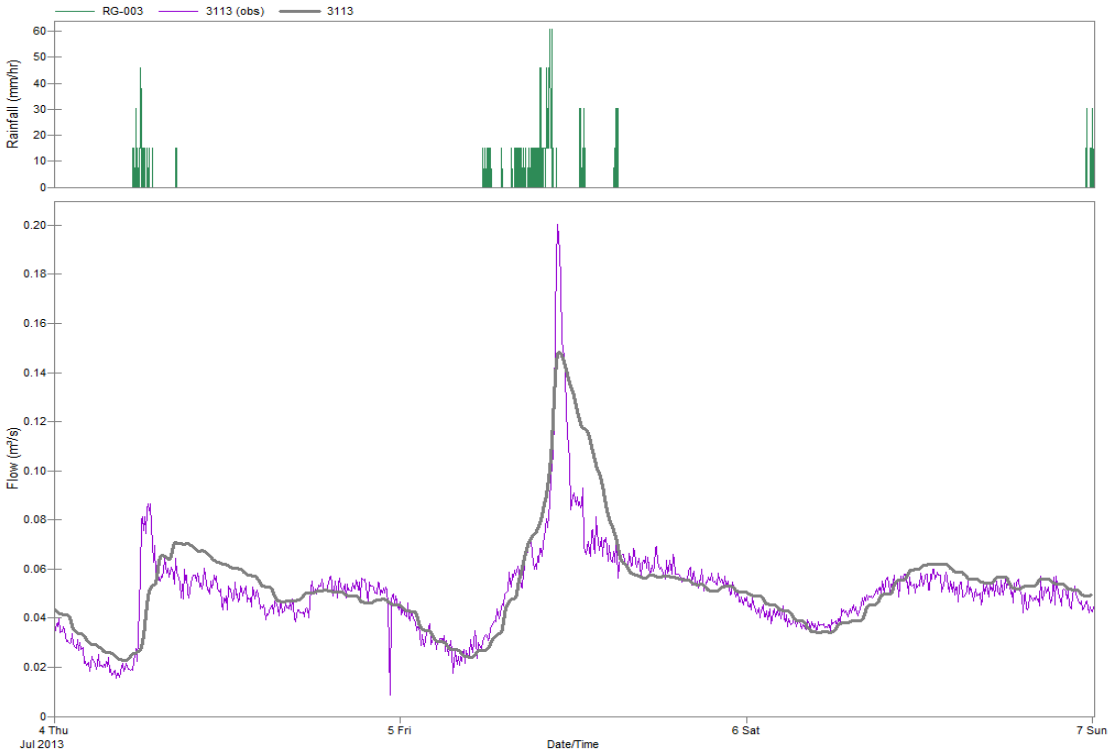
Monitor: FM-011 UNI-4

Conduit: 3113

Diameter: 600 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:57	72.24	42.4	109.2	0.200	0.148	0.050	0.053	13070	13790
Difference (%)					-26%		6%		6%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-011 UNI-4

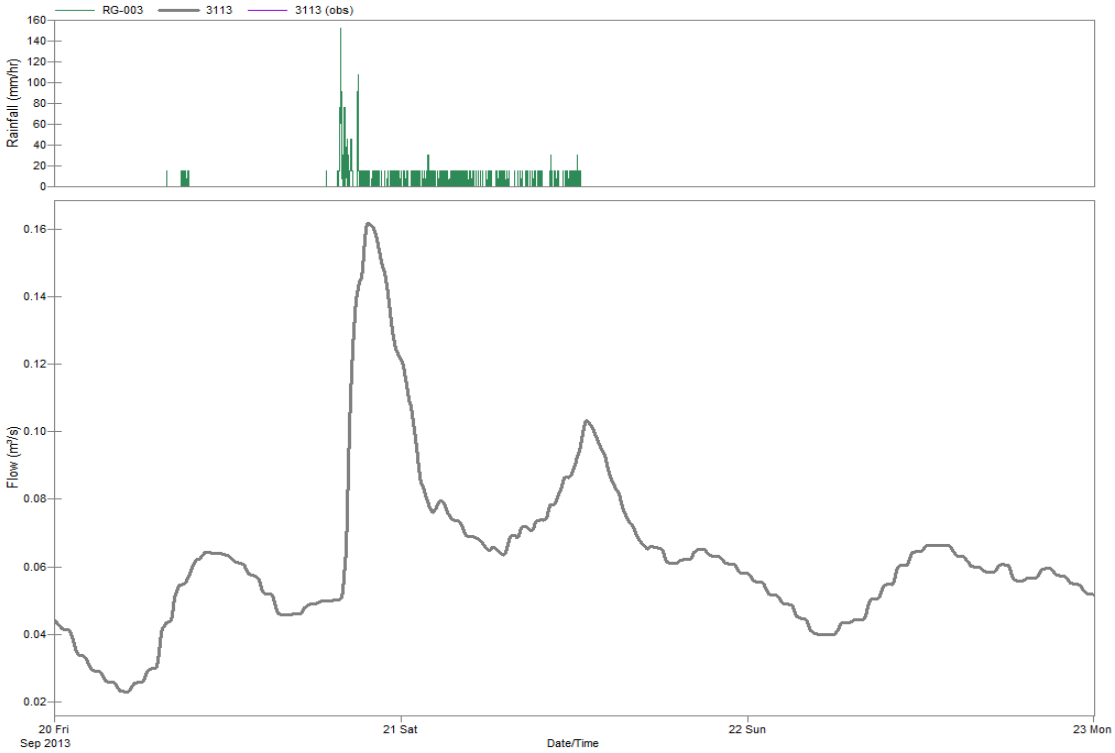
Conduit: 3113

Diameter: 600 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Note: Flow monitoring data is not available for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
9/19/2013 23:57	72	89.9	164.4	N/A	0.162	N/A	0.063	N/A	16390
Difference (%)					N/A		N/A		N/A



1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

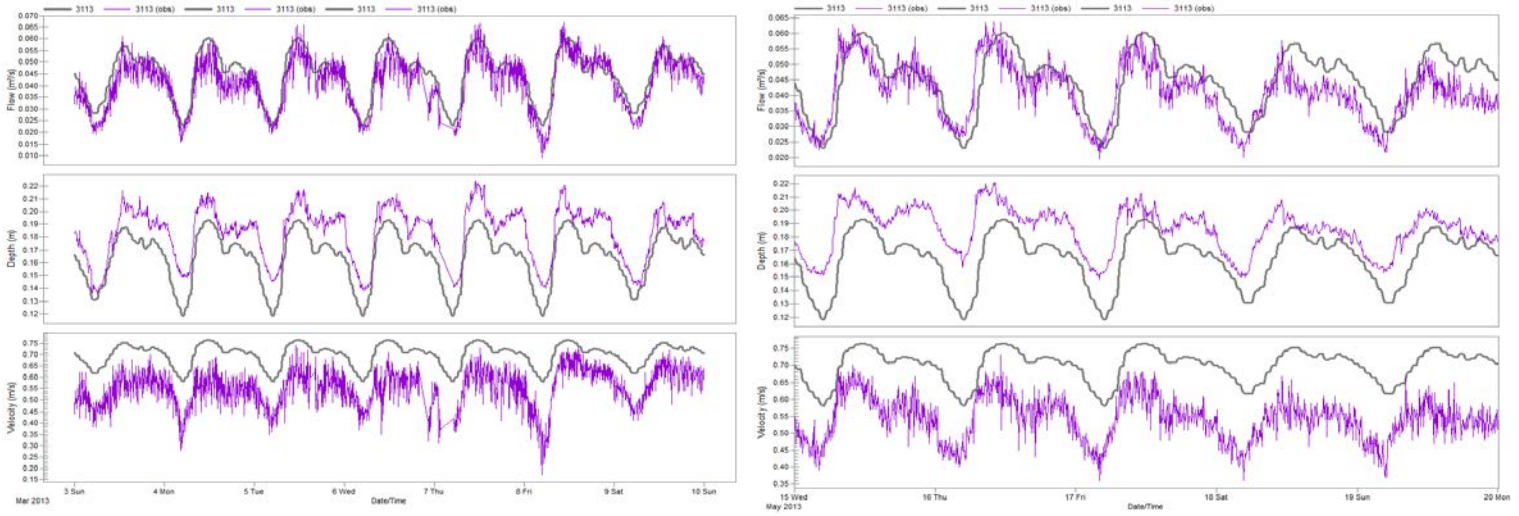
Monitor: FM-011 UNI-4

Conduit: 3113

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	March 3-9, 2013				May 13-19, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.107	0.108			0.107	0.108		
Base Flow (L/s)	12.46	12.40			12.46	12.398		
Population	13715	13700			13715	13700		
Per Capita (L/c/d)	162	208			162	208		
Avg. Sewage (L/s)	25.7	33.0			25.7	33.0		
Pipe (mm)	600	600			600	600		
Total Area (ha)	116.4	114.5			116.4	114.5		
Incremental Area (ha)	116.4	114.5			116.4	114.5		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.224	0.193	-0.031	-14%	0.221	0.193	-0.028	-13%
Q_{max} (m^3/s)	0.067	0.060	-0.007	-10%	0.064	0.060	-0.004	-6%
Vol (m^3)	24860	27020	2160	9%	17646	19299	1653	9%
Vel_{max} (m/s)	0.7	0.8	0.0	3%	0.7	0.8	0.0	5%

Graph



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-012 LRL-19

Conduit: 16062

Diameter: 1200 mm

Model Input Parameters

Parameter	1	2	3
R	0.003	0.000	0.001
T	0.20	22.80	24.00
K	46	5	4

R_{total}

0.4%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/27/2013 23:59	48.04	41.9	109.2	0.361	0.441	0.194	0.245	33580	42250
Difference (%)					22%		26%		26%

1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-012 LRL-19

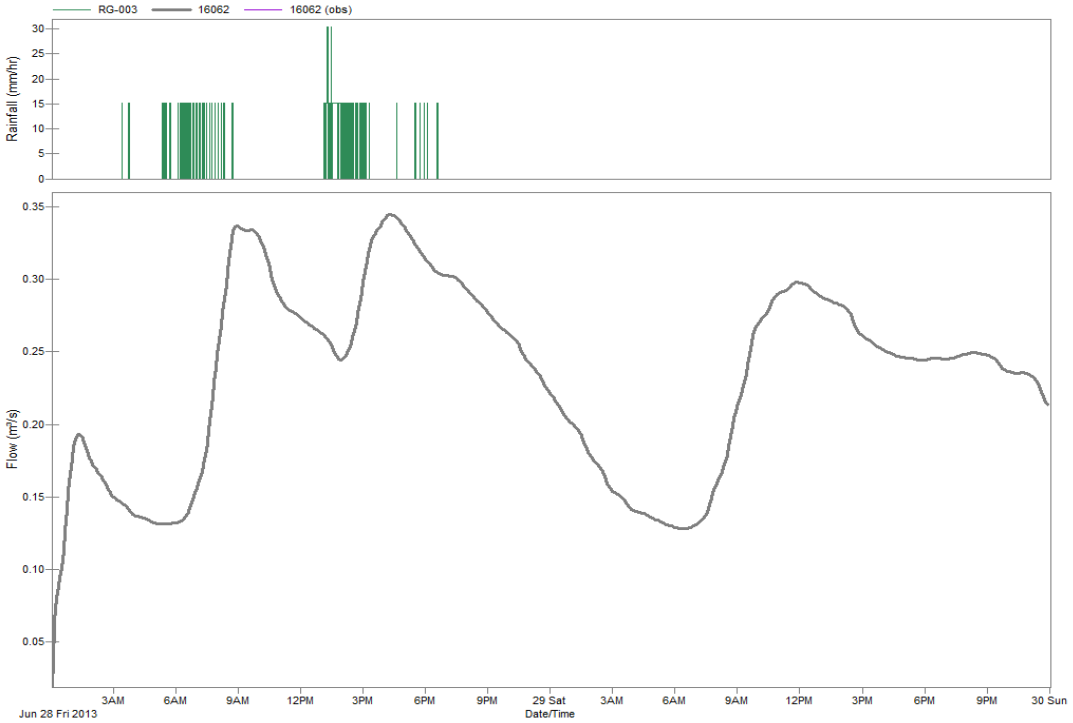
Conduit: 16062

Diameter: 1200 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Note: Flow monitoring data is not available for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/28/2013 0:01	48.02	31.6	39.6	N/A	0.345	N/A	0.232	N/A	40050
Difference (%)					N/A		N/A		N/A



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-012 LRL-19

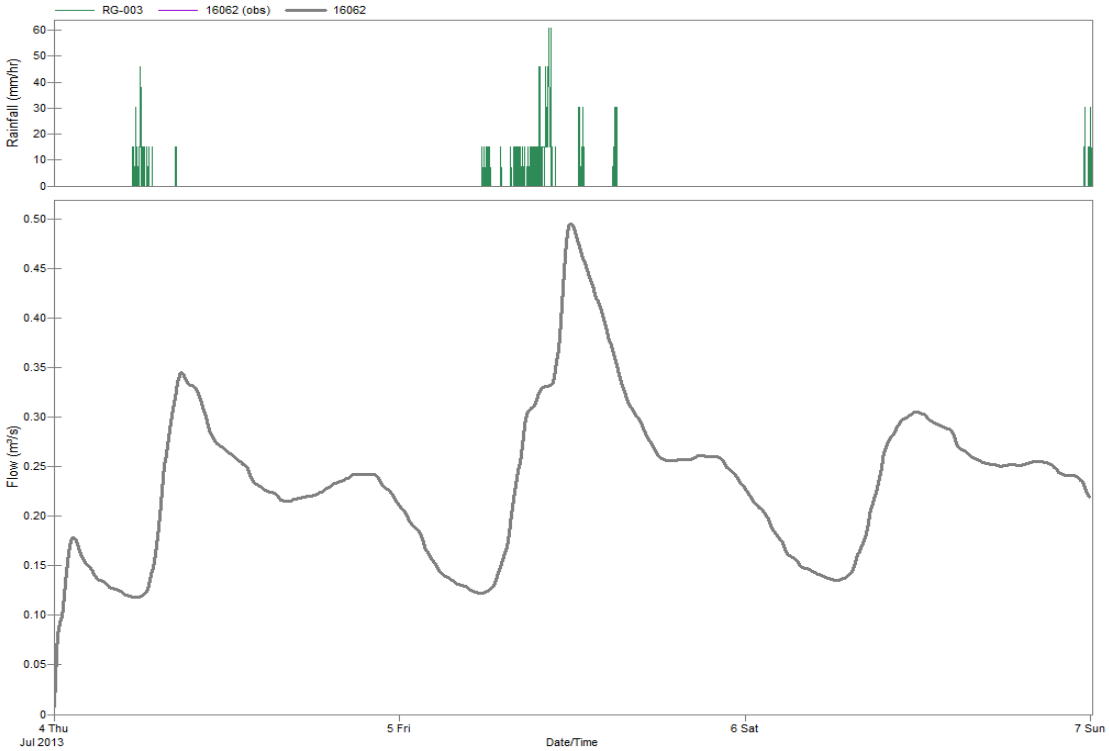
Conduit: 16062

Diameter: 1200 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Note: Flow monitoring data is not available for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:57	72.24	42.4	109.2	N/A	0.495	N/A	0.235	N/A	60940
Difference (%)					N/A		N/A		N/A



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-012 LRL-19

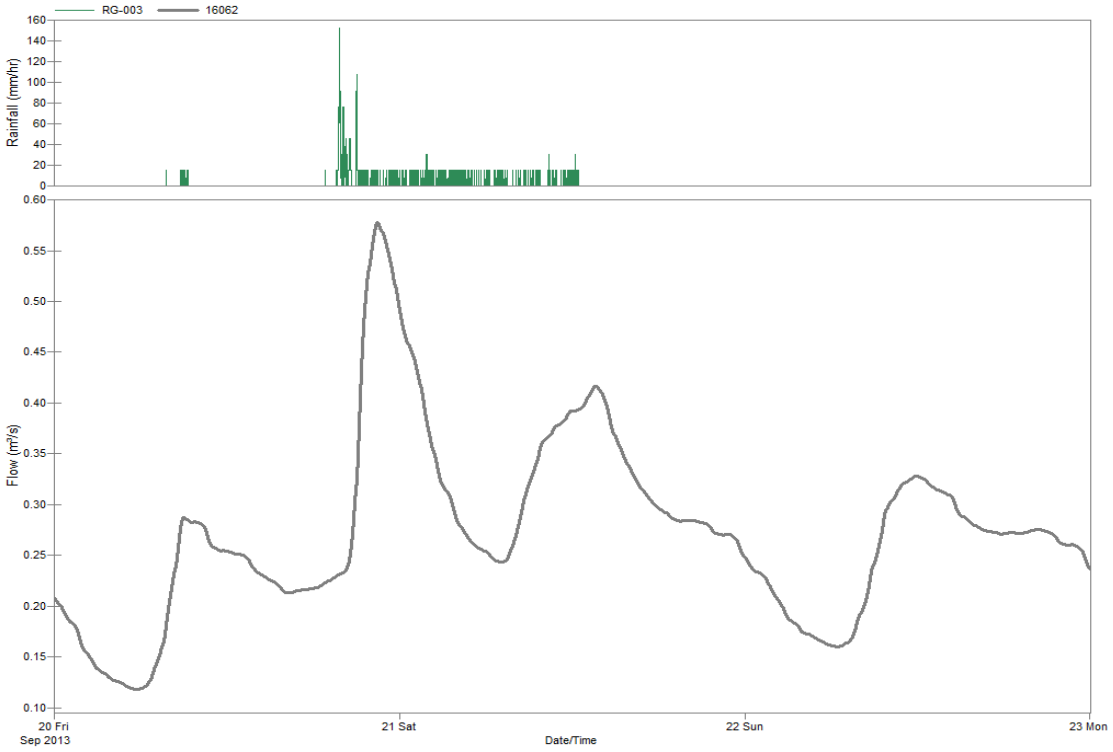
Conduit: 16062

Diameter: 1200 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Note: Flow monitoring data is not available for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
9/19/2013 23:57	72	89.9	164.4	N/A	0.578	N/A	0.273	N/A	70880
Difference (%)					N/A		N/A		N/A



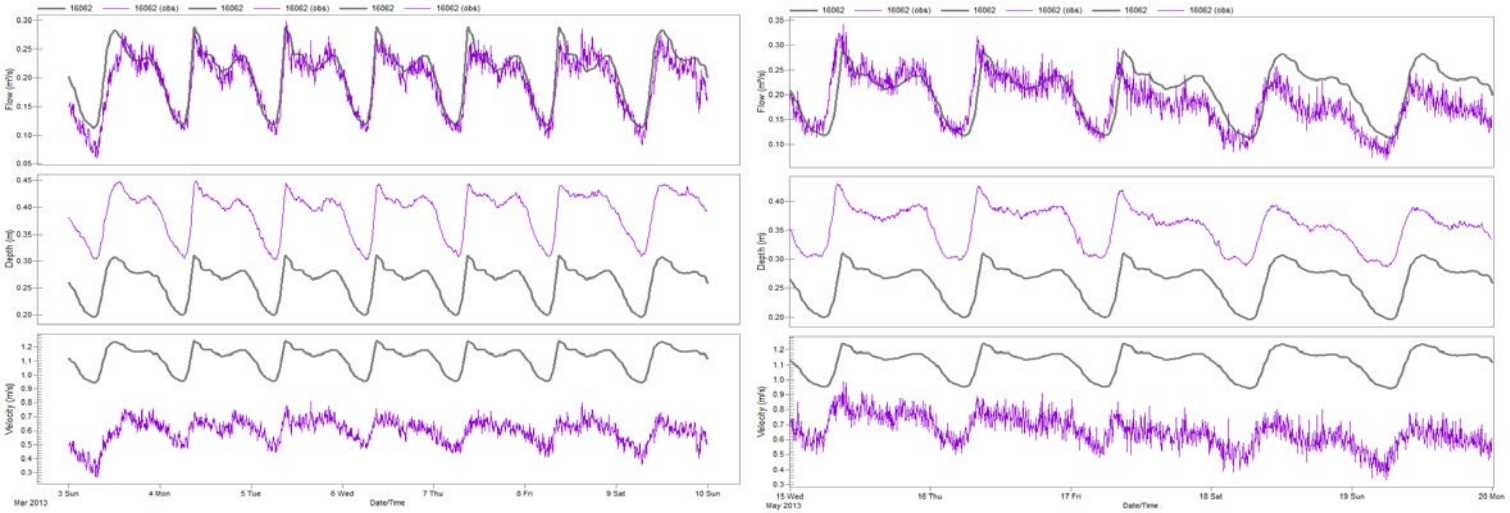
1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

			Target %	
Monitor:	FM-012	LRL-19	D_{max}	-20 to +20%
Conduit:	16062		Q_{max}	-15 to +15%
			Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	March 3-9, 2013				Date	May 15-19, 2013		
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.023	0.023			0.023	0.023		
Base Flow (L/s)	12.54	12.67			12.54	12.67		
Population	49082	48979			49082	48979		
Per Capita (L/c/d)	125	170			125	170		
Avg. Sewage (L/s)	71.2	96.4			71.2	96.4		
Pipe (mm)	1200	1200			1200	1200		
Total Area (ha)	1186.1	1161.6			1186.1	1161.6		
Incremental Area (ha)	544.7	539.3			544.7	539.3		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.450	0.310	-0.139	-31%	0.431	0.310	-0.121	-28%
Q_{max} (m^3/s)	0.298	0.288	-0.010	-3%	0.344	0.288	-0.055	-16%
Vol (m^3)	116652	124631	7979	7%	80399	89052	8653	11%
Vel_{max} (m/s)	0.8	1.2	0.4	53%	1.0	1.2	0.3	26%

Graph



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-013 WLM-1B

Conduit: 2925

Diameter: 550 mm

Model Input Parameters

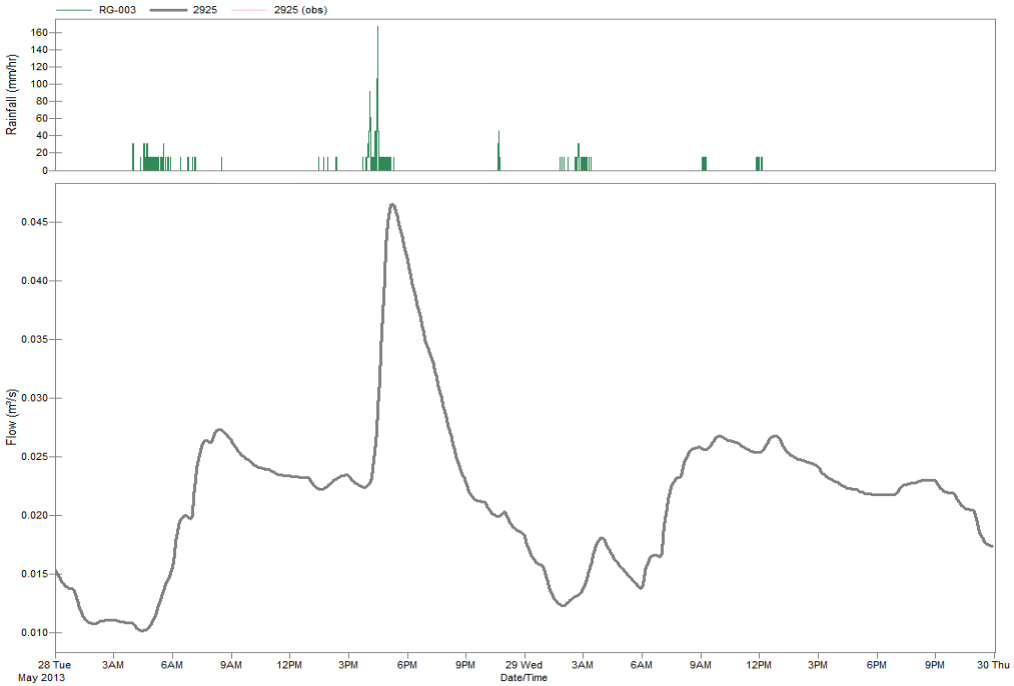
Parameter	1	2	3
R	0.009	0.005	0.001
T	0.20	12.00	24.00
K	20	6	4

R_{total} 1.5%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Note: Flow monitoring data is not available for this event

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/27/2013 23:59	48.04	41.9	109.2	N/A	0.047	N/A	0.022	N/A	3745
Difference (%)					N/A		N/A		N/A



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

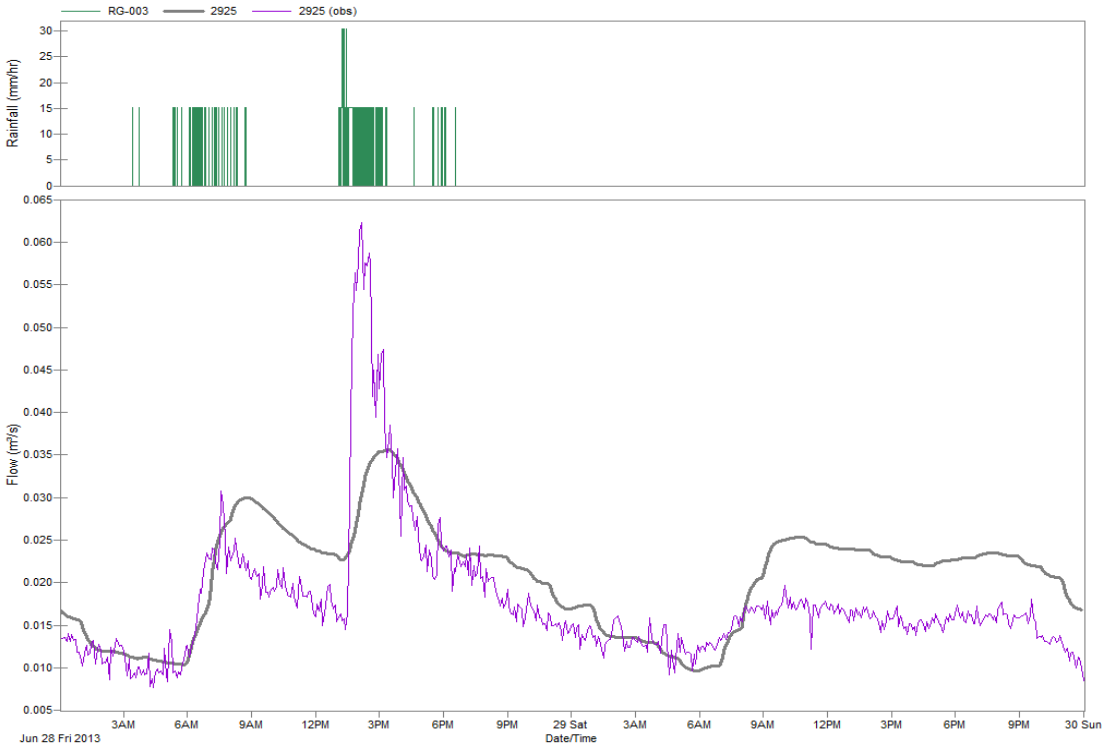
Monitor: FM-013 WLM-1B

Conduit: 2925

Diameter: 550 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m³/s)	Current Max (m³/s)	Observed Mean (m³/s)	Current Mean (m³/s)	Observed Total (m³)	Current Total (m³)
6/28/2013 0:01	48.02	31.6	39.6	0.062	0.036	0.018	0.021	3042	3559
Difference (%)					-43%		17%		17%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

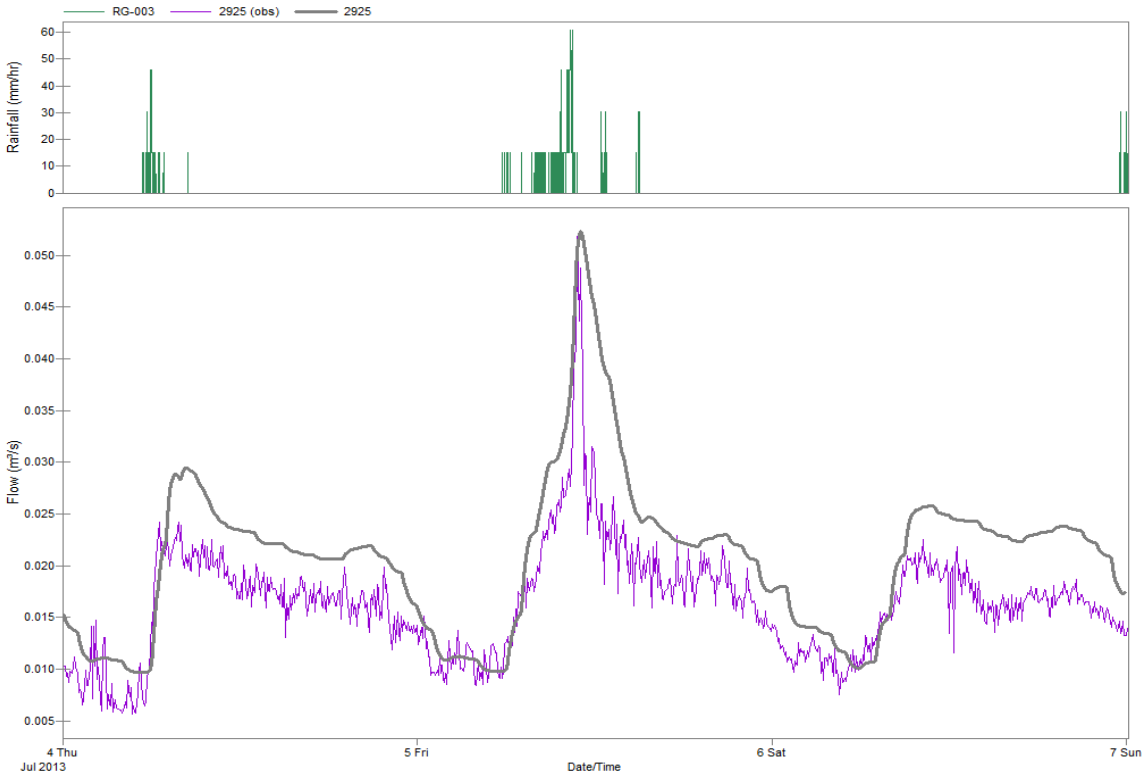
Monitor: FM-013 WLM-1B

Conduit: 2925

Diameter: 550 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:57	72.24	42.4	109.2	0.052	0.052	0.016	0.021	4262	5390
Difference (%)					1%		27%		26%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

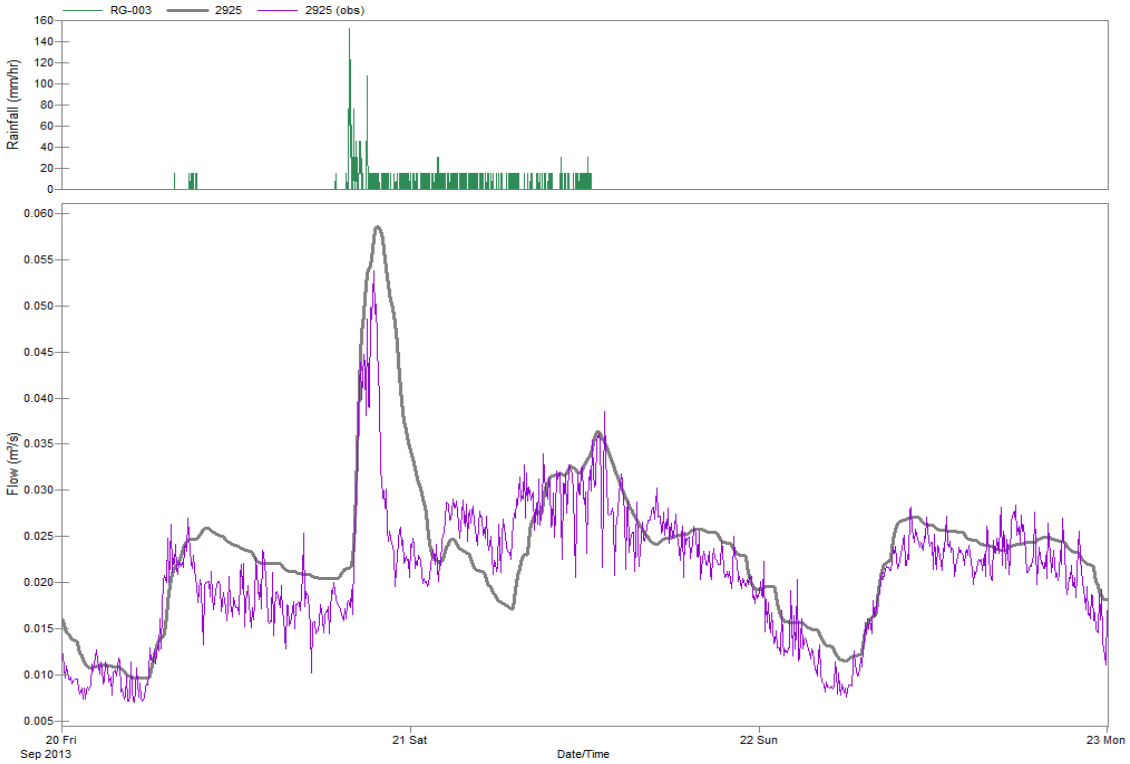
Monitor: FM-013 WLM-1B

Conduit: 2925

Diameter: 550 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
9/19/2013 23:57	72	89.9	164.4	0.054	0.059	0.021	0.023	5461	6086
Difference (%)					9%		11%		11%



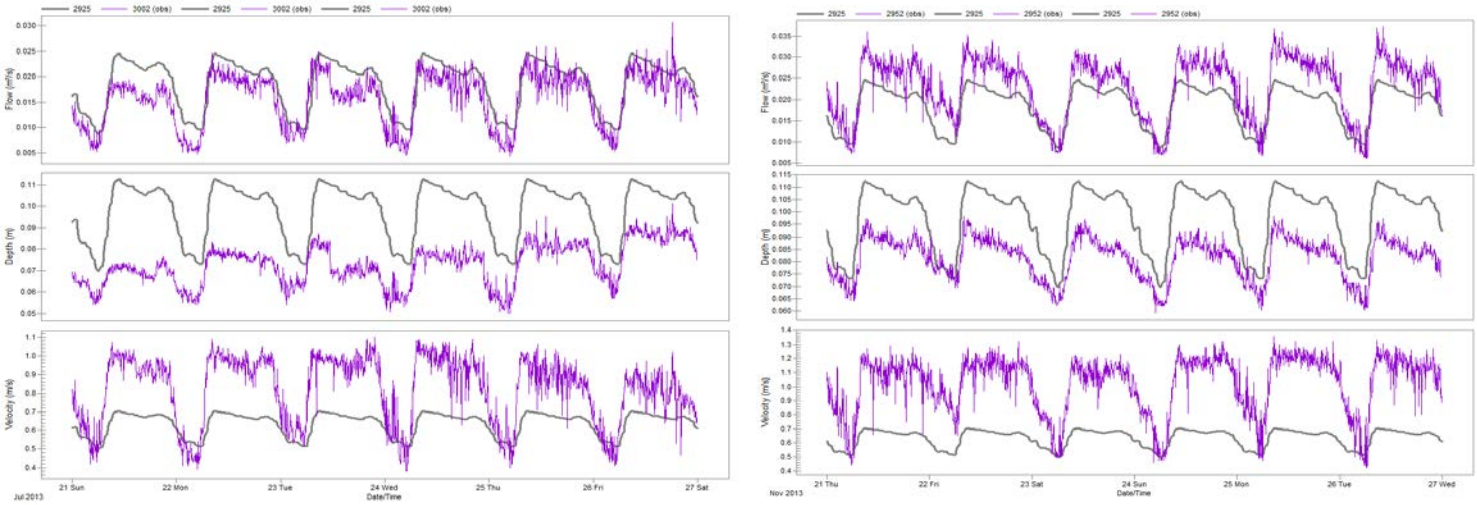
1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

			Target %	
Monitor:	FM-013	WLM-1B	D_{max}	-20 to +20%
Conduit:	2925		Q_{max}	-15 to +15%
			Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	July 21-26, 2013				November 21-26, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.042	0.042			0.042	0.042		
Base Flow (L/s)	4.68	4.43			4.68	4.43		
Population	6492	6479			6492	6479		
Per Capita (L/c/d)	189	189			189	189		
Avg. Sewage (L/s)	14.2	14.2			14.2	14.2		
Pipe (mm)	550	550			550	550		
Total Area (ha)	111.1	105.2			111.1	105.2		
Incremental Area (ha)	111.1	105.2			111.1	105.2		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.101	0.113	0.011	11%	0.098	0.113	0.014	14%
Q_{max} (m^3/s)	0.031	0.025	-0.006	-20%	0.037	0.025	-0.013	-34%
Vol (m^3)	8147	9655	1508	19%	11969	9653	-2316	-19%
Vel_{max} (m/s)	1.1	0.7	-0.4	-36%	1.4	0.7	-0.7	-48%

Graph



1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

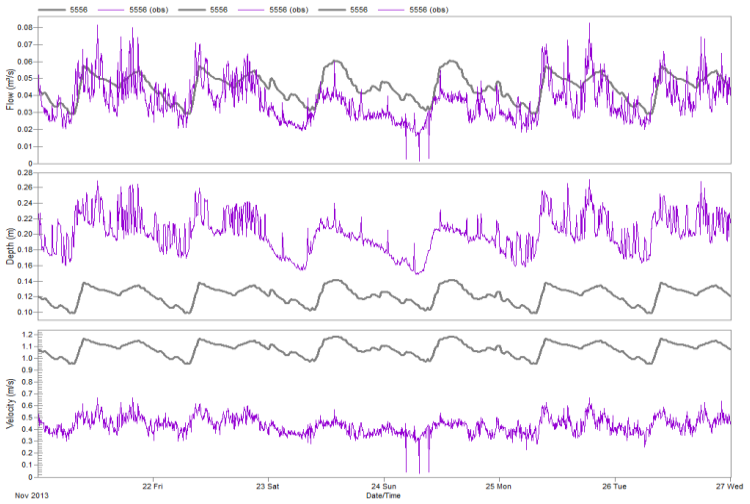
Monitor: FM-014 FWL-22

Conduit: 5556

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	N/A				November 21-26, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	N/A	N/A			0.061	0.059		
Base Flow (L/s)	N/A	N/A			6.21	6.224		
Population	N/A	N/A			10948	10948		
Per Capita (L/c/d)	N/A	N/A			130	122		
Avg. Sewage (L/s)	N/A	N/A			16.5	15.5		
Pipe (mm)	N/A	N/A			600	600		
Total Area (ha)	N/A	N/A			102.0	105.8		
Incremental Area (ha)					102.0	105.8		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	N/A	N/A	N/A	N/A	0.271	0.142	-0.129	-48%
Q_{max} (m^3/s)	N/A	N/A	N/A	N/A	0.083	0.060	-0.022	-27%
Vol (m^3)	N/A	N/A	N/A	N/A	19289	23315	4026	21%
Vel_{max} (m/s)	N/A	N/A	N/A	N/A	0.7	1.2	0.5	77%

Graph



1611-11191: Waterloo Sanitary Master Plan

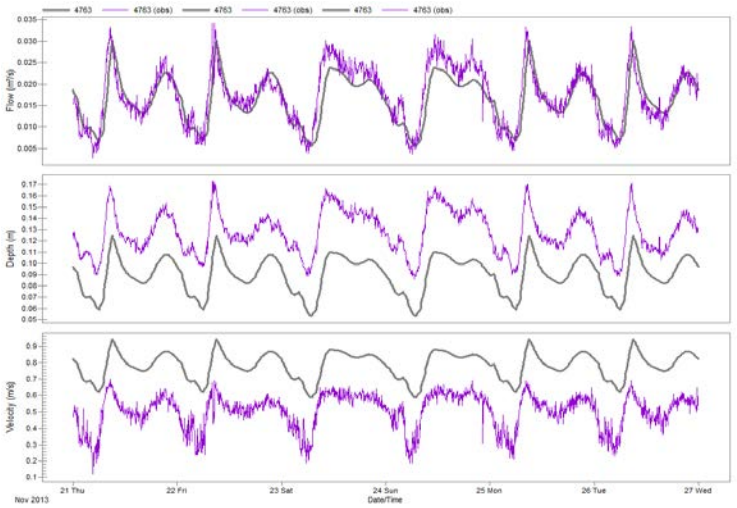
Dry Weather Calibration - Final

Monitor:	FM-015	FWL-50
Conduit:	4763	

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	N/A				November 21-26, 2013			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	N/A	N/A			0.023	0.023		
Base Flow (L/s)	N/A	N/A			2.96	2.927		
Population	N/A	N/A			5505	5505		
Per Capita (L/c/d)	N/A	N/A			213	213		
Avg. Sewage (L/s)	N/A	N/A			13.5	13.54		
Pipe (mm)	N/A	N/A			375	375		
Total Area (ha)	N/A	N/A			131.1	129.7		
Incremental Area (ha)	N/A	N/A			131.1	129.7		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	N/A	N/A	N/A	N/A	0.173	0.124	-0.049	-28%
Q_{max} (m^3/s)	N/A	N/A	N/A	N/A	0.034	0.030	-0.004	-12%
Vol (m^3)	N/A	N/A	N/A	N/A	8998	8537	-461	-5%
Vel_{max} (m/s)	N/A	N/A	N/A	N/A	0.7	0.9	0.2	35%

Graph



1611-11191: Waterloo Master Plan Update

Dry Weather Flow Calibration/Validation Results

Last Updated: 27-Jun-14

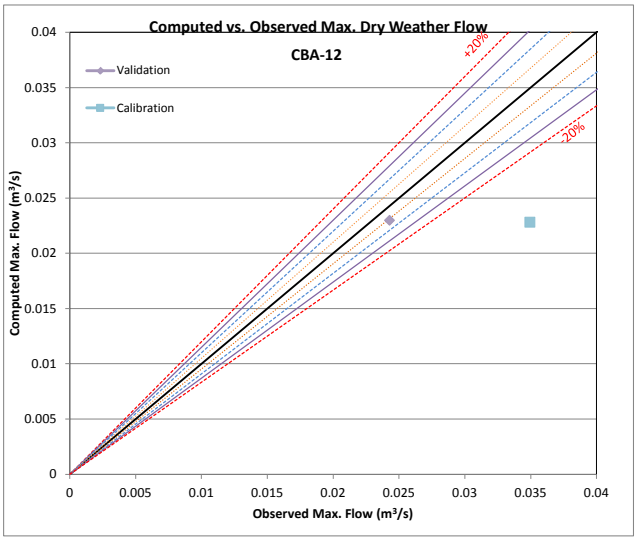
Monitor		Peak Observed Flow (m^3/s)		Peak Simulated Flow (m^3/s)		% Difference in Peak Flow	
		Calibration	Validation	Calibration	Validation	Calibration	Validation
CBA-12	FM-001	0.035	0.024	0.023	0.023	-35%	-5%
FWL-4A	FM-002	0.265	0.173	0.236	0.236	-11%	36%
GLN-4	FM-003	0.017	0.017	0.014	0.014	-19%	-21%
LEE-9	FM-004	0.125	0.124	0.100	0.106	-20%	-15%
LEX-8A	FM-005	0.214	0.245	0.189	0.189	-12%	-23%
LRL-56	FM-006	0.092	0.100	0.084	0.084	-10%	-16%
LWD-6	FM-007	0.049	0.060	0.052	0.049	6%	-18%
KEA-30	FM-008	0.016	0.018	0.015	0.015	-5%	-13%
MPL-63	FM-009	0.016	0.015	0.014	0.014	-10%	-4%
L31-3	FM-010	0.014	0.012	0.011	0.011	-21%	-10%
UNI-4	FM-011	0.067	0.064	0.060	0.060	-10%	-6%
LRL-19	FM-012	0.298	0.344	0.288	0.288	-3%	-16%
WLM-1B	FM-013	0.031	0.037	0.025	0.025	-20%	-34%

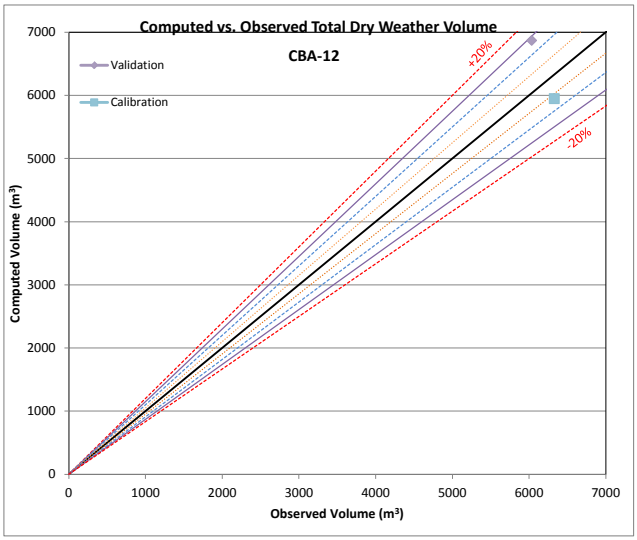
1611-11191: Waterloo Master Plan Update
Dry Weather Flow Calibration/Validation Results
Last Updated: 27-Jun-14

Monitor		Observed Flow Vol. (m^3)		Simulated Flow Vol. (m^3)		% Difference in Flow Volume	
		Calibration	Validation	Calibration	Validation	Calibration	Validation
CBA-12	FM-001	6327	6033	5947	6870	-6%	14%
FWL-4A	FM-002	78187	49457	78458	77542	0%	57%
GLN-4	FM-003	3753	3555	3720	3715	-1%	5%
LEE-9	FM-004	33560	36497	33365	33375	-1%	-9%
LEX-8A	FM-005	19937	20558	27634	27634	39%	34%
LRL-56	FM-006	32142	25467	30964	25813	-4%	1%
LWD-6	FM-007	14263	17652	16054	16949	13%	-4%
KEA-30	FM-008	5868	3885	5728	4092	-2%	5%
MPL-63	FM-009	3996	2662	4003	2860	0%	7%
L31-3	FM-010	4367	2943	4590	3278	5%	11%
UNI-4	FM-011	24860	17646	27020	19299	9%	9%
LRL-19	FM-012	116652	80399	124631	89052	7%	11%
WLM-1B	FM-013	8147	11969	9655	9653	19%	-19%

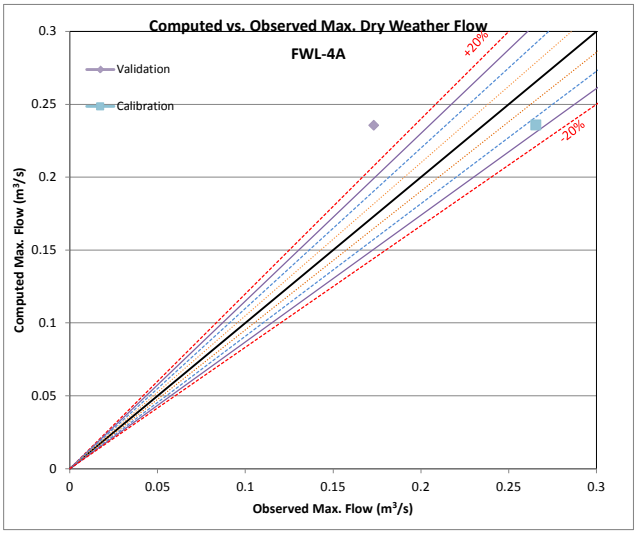
1611-11191: Waterloo Master Plan Update
Dry Weather Flow Calibration/Validation Plots

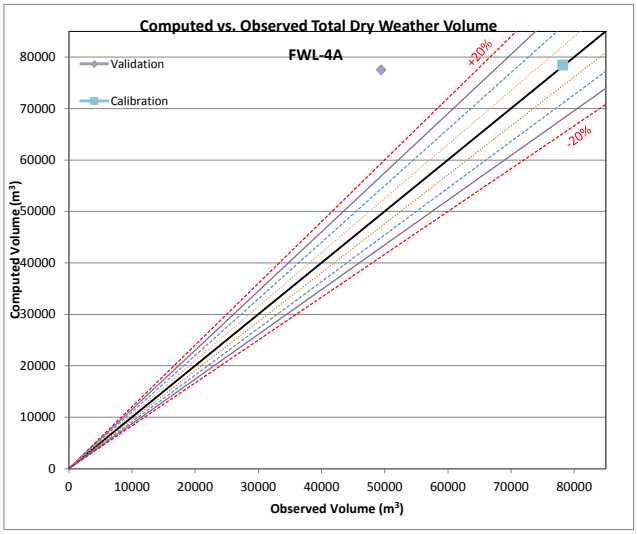
CBA-12



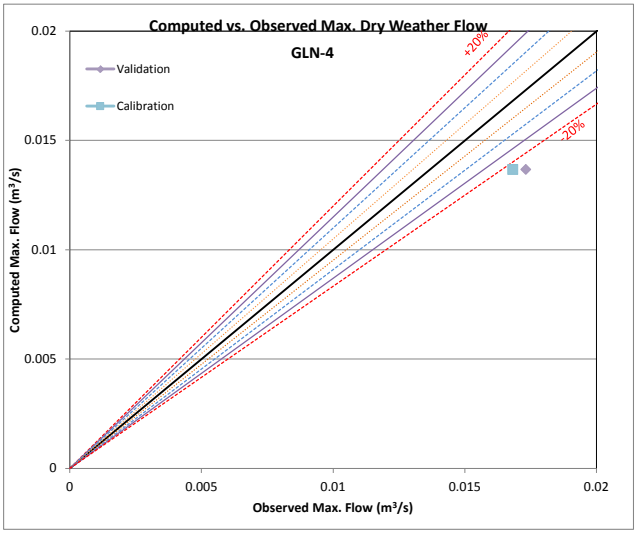


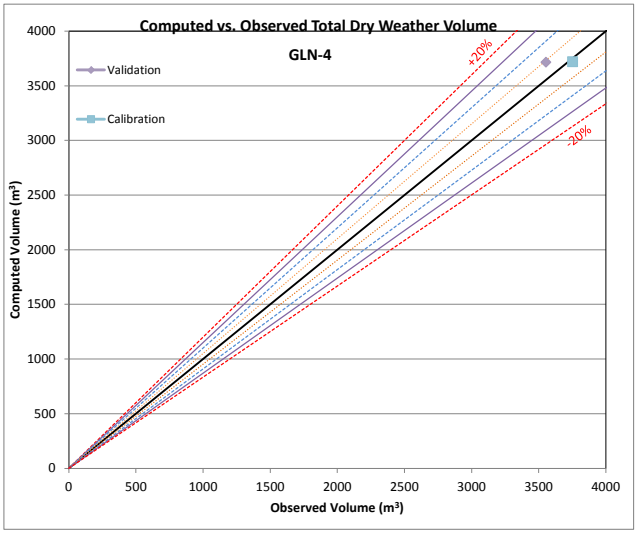
FWL-4A





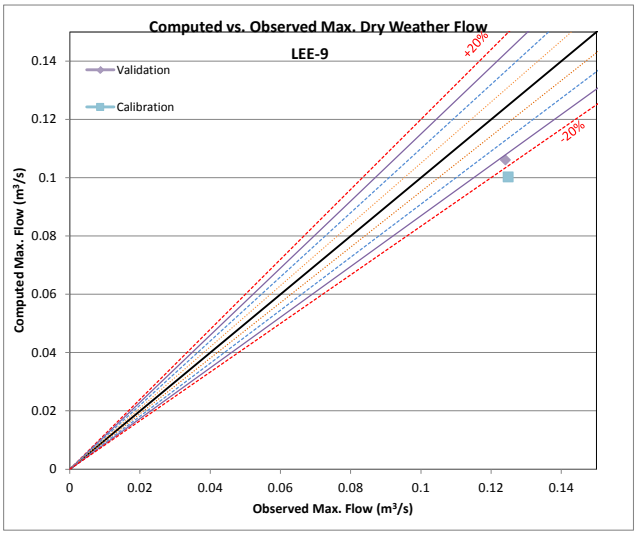
GLN-4

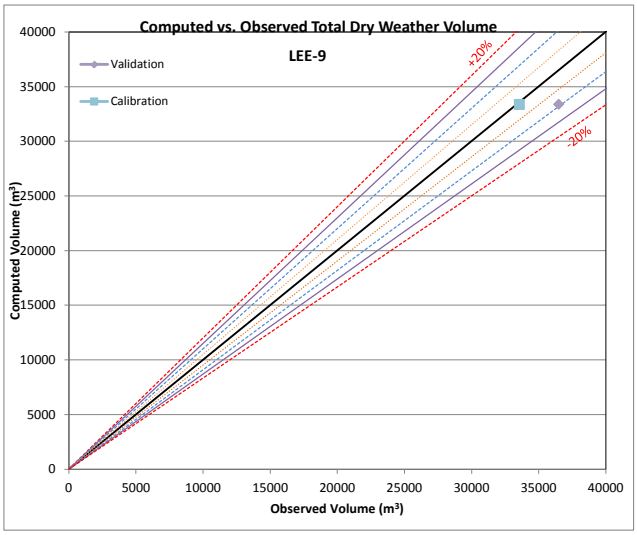




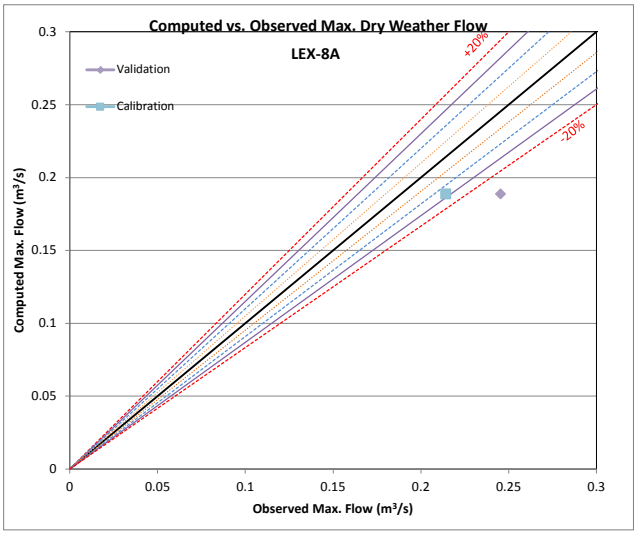
1611-11191: Waterloo Master Plan Update
Dry Weather Flow Calibration/Validation Plots

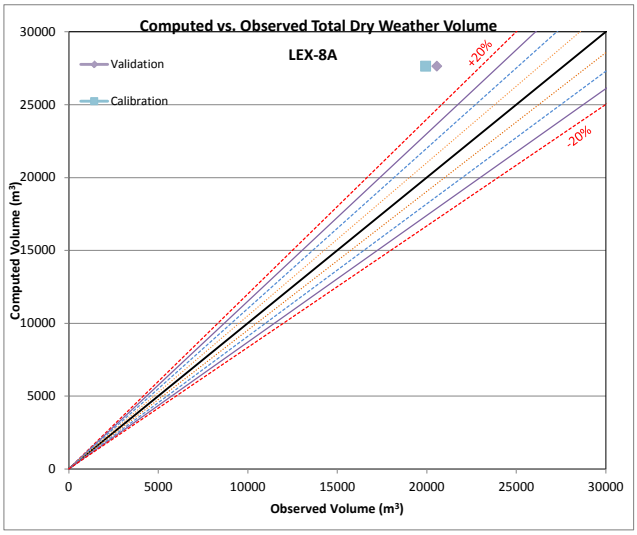
LEE-9



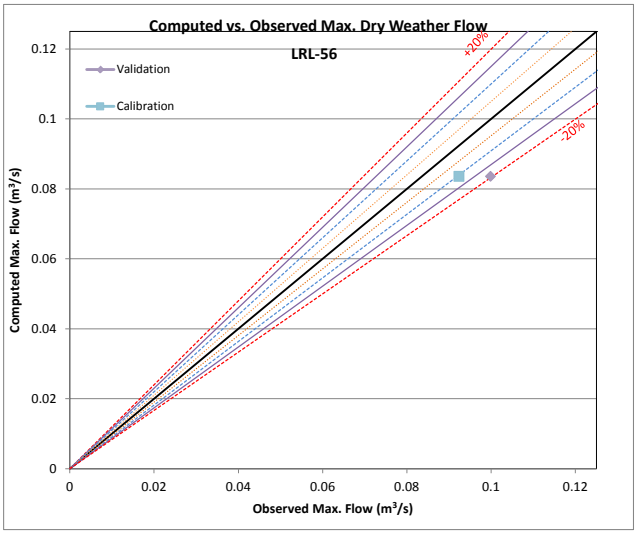


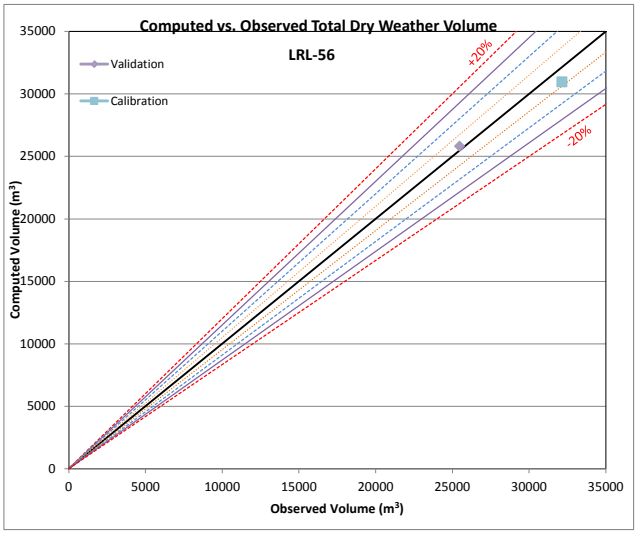
LEX-8A





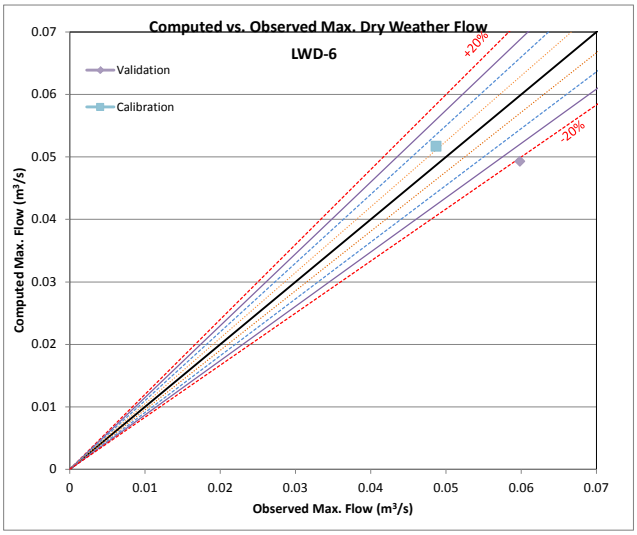
LRL-56

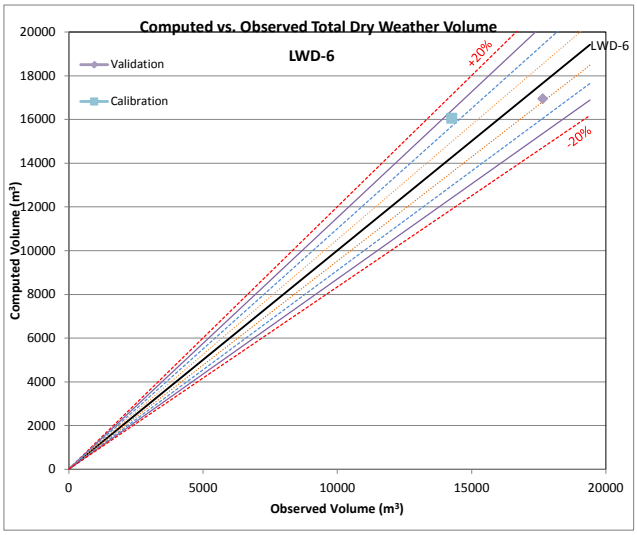




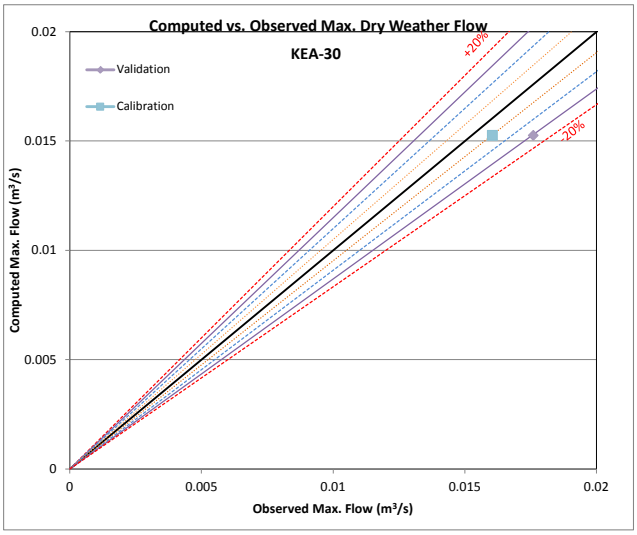
1611-11191: Waterloo Master Plan Update
Dry Weather Flow Calibration/Validation Plots

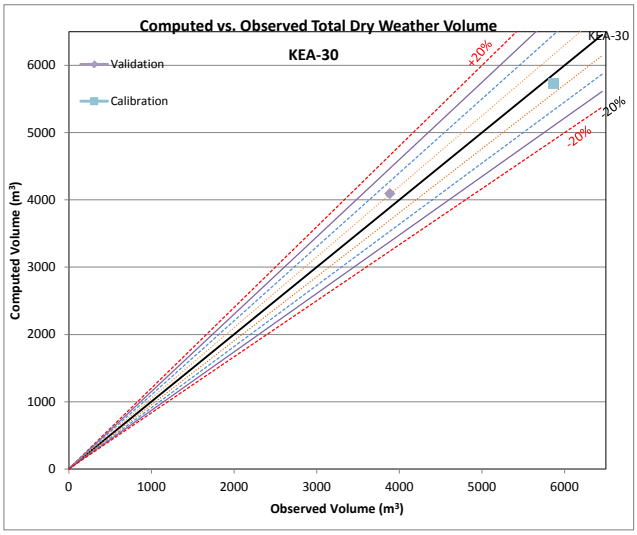
LWD-6



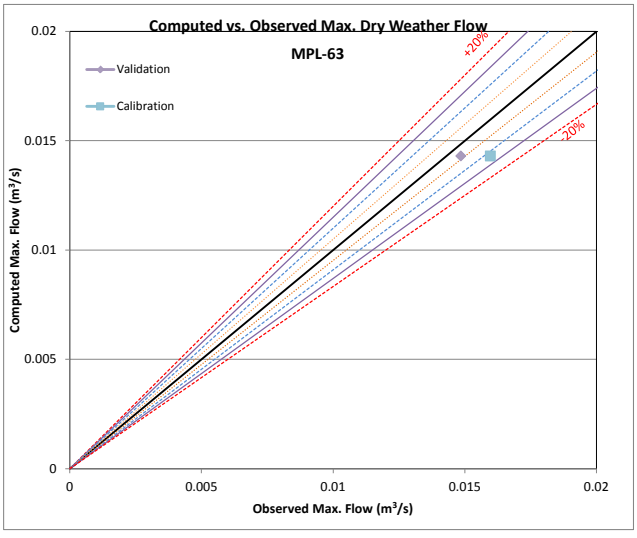


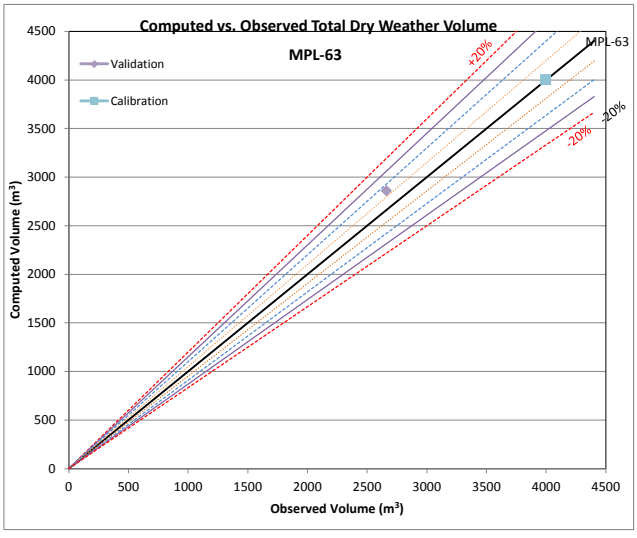
KEA-30





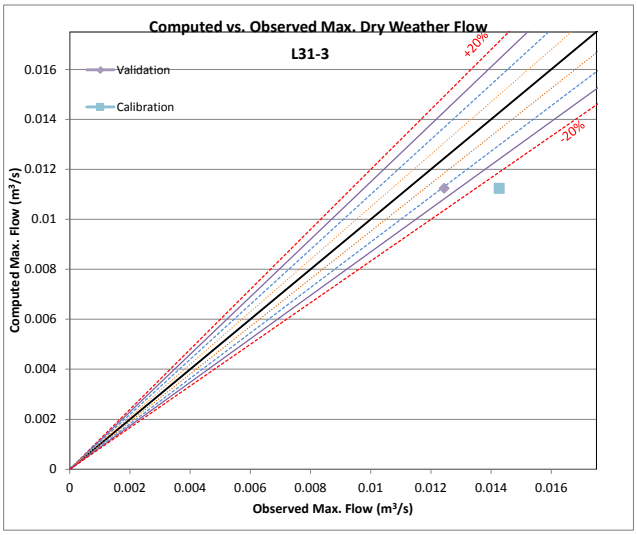
MPL-63

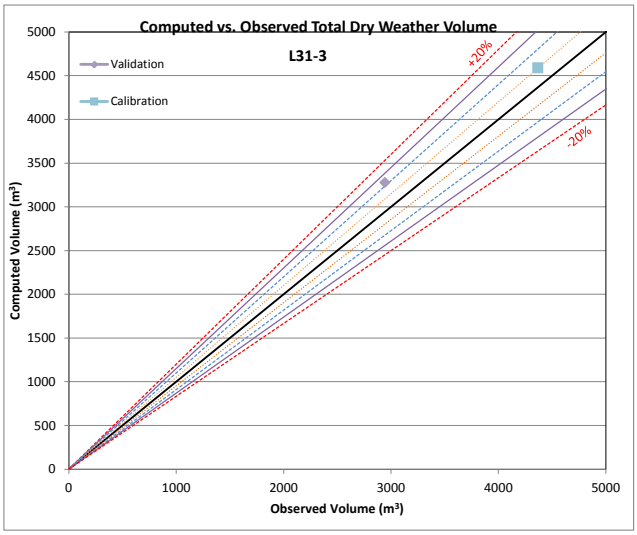




1611-11191: Waterloo Master Plan Update
Dry Weather Flow Calibration/Validation Plots

L31-3





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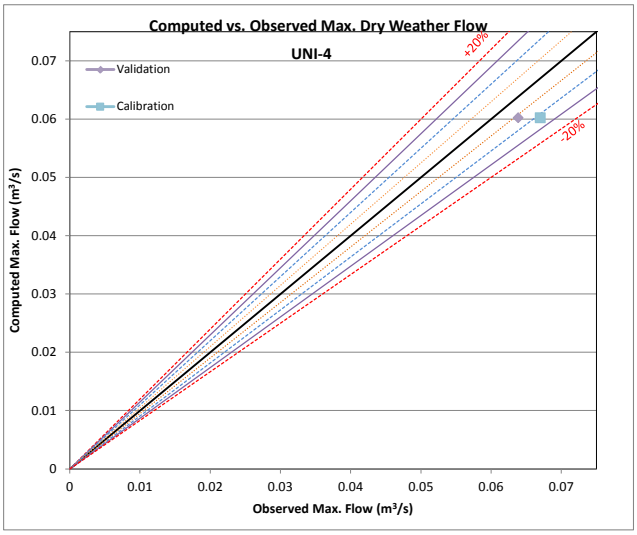
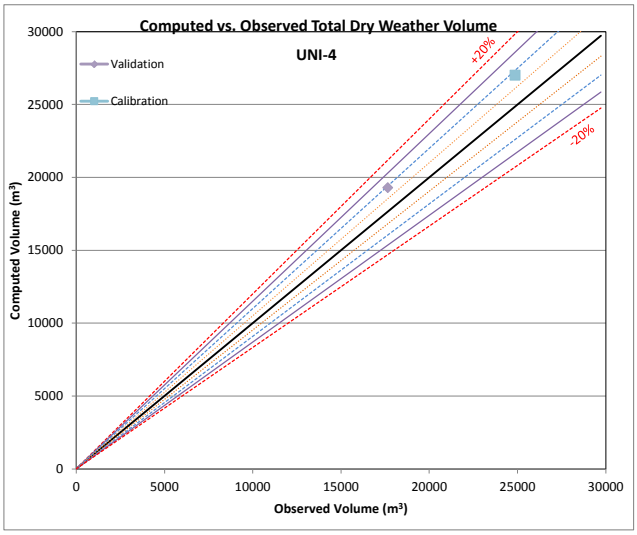
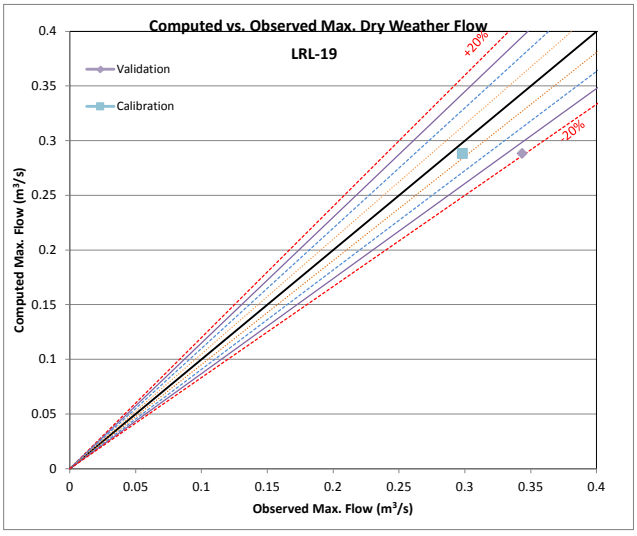
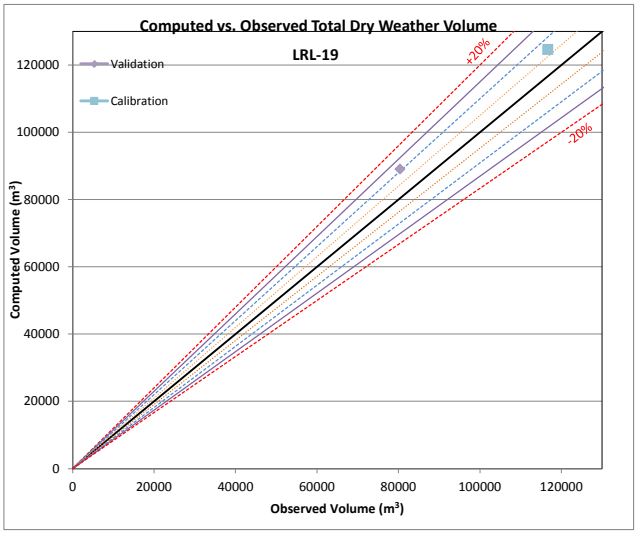




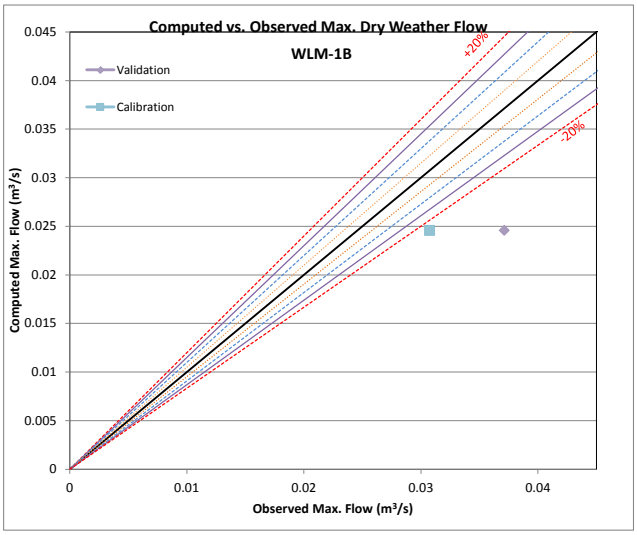
LRL-19

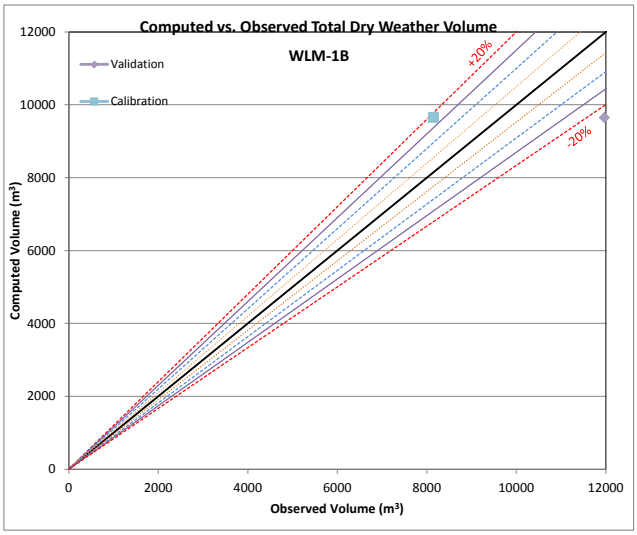




1611-11191: Waterloo Master Plan Update
Dry Weather Flow Calibration/Validation Plots

WLM-1B





1611-11191: Waterloo Master Plan Update

Wet Weather Flow Calibration/Validation Results

Last Updated: 6/27/2014

Monitor		Peak Observed Flow (m^3/s)				Peak Simulated Flow (m^3/s)				% Difference in Peak Flow			
		28-May	28-Jun	4-Jul	20-Sep	28-May	28-Jun	4-Jul	20-Sep	28-May	28-Jun	4-Jul	20-Sep
CBA-12	FM-001	0.041	0.043	0.056	0.041	0.025	0.023	0.025	0.027	-40%	-47%	-55%	-34%
FWL-4A	FM-002	0.257	0.485	0.599	0.630	0.469	0.354	0.531	0.655	82%	-27%	-11%	4%
GLN-4	FM-003	0.025	0.054	0.041	0.029	0.027	0.018	0.030	0.036	8%	-67%	-27%	23%
LEE-9	FM-004	0.122	0.176	0.164	0.147	0.162	0.144	0.164	0.208	33%	-18%	0%	42%
LEX-8A	FM-005	0.155	0.171	0.168	0.141	0.074	0.089	0.105	0.091	-52%	-48%	-38%	-36%
LRL-56	FM-006	0.102	0.175	0.200	N/A	0.148	0.114	0.165	0.199	45%	-35%	-17%	N/A
LWD-6	FM-007	0.059	0.065	0.072	0.080	0.066	0.058	0.071	0.079	12%	-11%	-2%	-1%
KEA-30	FM-008	0.014	0.019	N/A	N/A	0.016	0.015	0.016	0.015	13%	-18%	N/A	N/A
MPL-63	FM-009	0.023	0.038	0.059	N/A	0.035	0.023	0.038	0.050	51%	-41%	-34%	N/A
L31-3	FM-010	0.009	N/A	N/A	N/A	0.011	0.011	0.013	0.012	30%	N/A	N/A	N/A
UNI-4	FM-011	0.069	0.277	0.200	N/A	0.127	0.093	0.148	0.162	85%	-66%	-26%	N/A
LRL-19	FM-012	0.361	N/A	N/A	N/A	0.441	0.345	0.495	0.578	22%	N/A	N/A	N/A
WLM-1B	FM-013	N/A	0.062	0.052	0.054	0.047	0.036	0.052	0.059	N/A	-43%	1%	9%

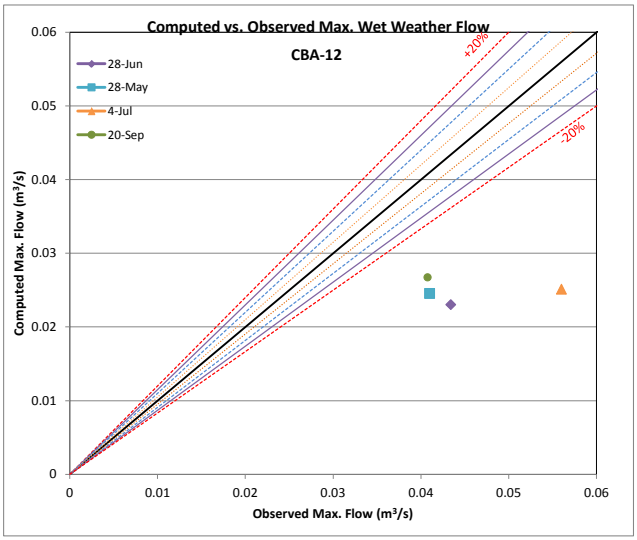
1611-11191: Waterloo Master Plan Update

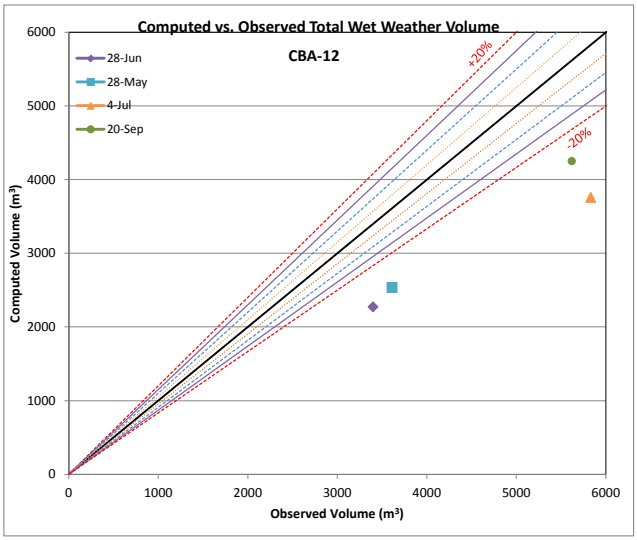
Wet Weather Flow Calibration/Validation Results

Last Updated: 6/27/2014

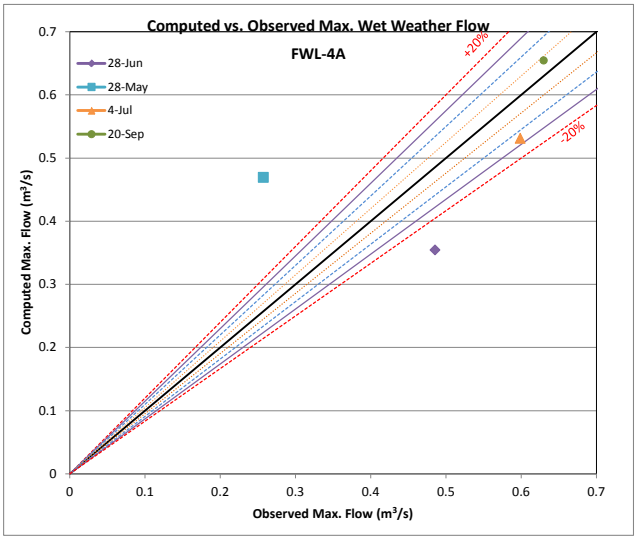
Monitor		Observed Flow Vol. (m^3)				Simulated Flow Vol. (m^3)				% Difference in Flow Volume			
		28-May	28-Jun	4-Jul	20-Sep	28-May	28-Jun	4-Jul	20-Sep	28-May	28-Jun	4-Jul	20-Sep
CBA-12	FM-001	3611	3399	5833	5619	2534	2271	3758	4250	-30%	-33%	-36%	-24%
FWL-4A	FM-002	21390	25860	38790	58470	34070	31140	47510	57490	59%	20%	22%	-2%
GLN-4	FM-003	1814	2329	2764	2450	1809	1629	2512	3296	0%	-30%	-9%	35%
LEE-9	FM-004	12080	14780	20890	21220	15900	14420	22220	29380	32%	-2%	6%	38%
LEX-8A	FM-005	8449	8464	11940	8444	8407	9198	14330	13830	0%	9%	20%	64%
LRL-56	FM-006	11740	13210	20200	N/A	13470	12540	19240	23920	15%	-5%	-5%	N/A
LWD-6	FM-007	5912	5700	8549	11570	6859	6285	9813	11510	16%	10%	15%	-1%
KEA-30	FM-008	1436	1442	N/A	N/A	1705	1689	2556	2697	19%	17%	N/A	N/A
MPL-63	FM-009	1505	1887	2366	N/A	1912	1648	2518	3430	27%	-13%	6%	N/A
L31-3	FM-010	857.1	N/A	N/A	N/A	1350	1335	2009	2067	58%	N/A	N/A	N/A
UNI-4	FM-011	7059	8249	13070	N/A	9745	9081	13790	16390	38%	10%	6%	N/A
LRL-19	FM-012	33580	N/A	N/A	N/A	42250	40050	60940	70880	26%	N/A	N/A	N/A
WLM-1B	FM-013	N/A	3042	4262	5461	3745	3559	5390	6086	N/A	17%	26%	11%

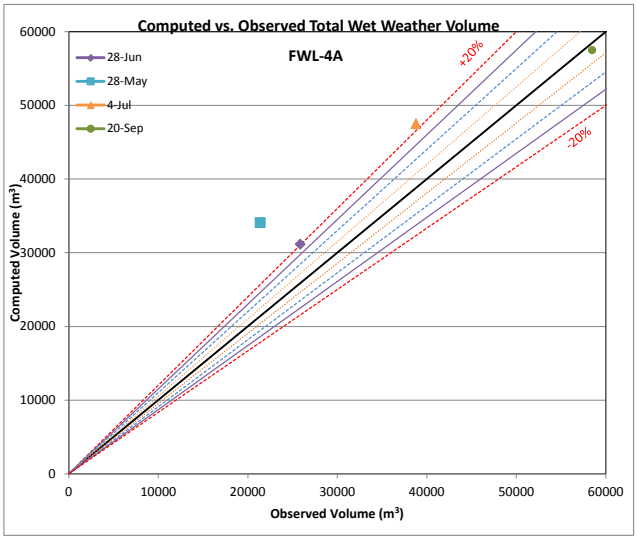
CBA-12



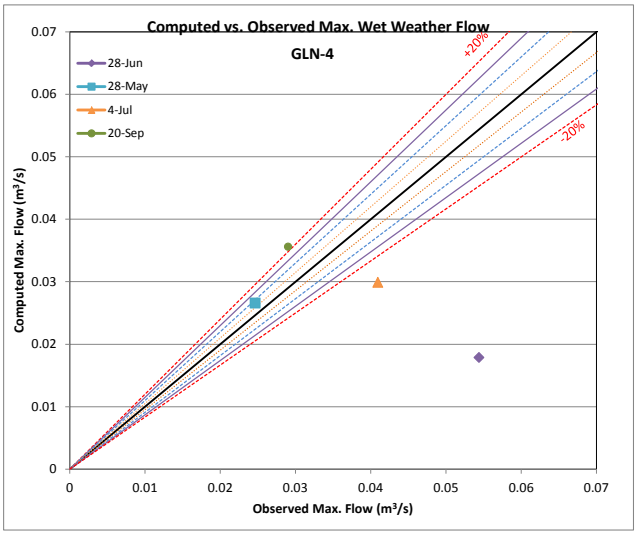


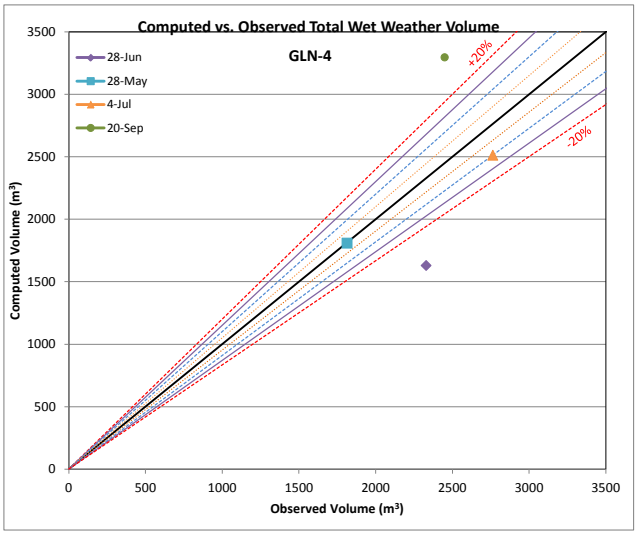
FWL-4A





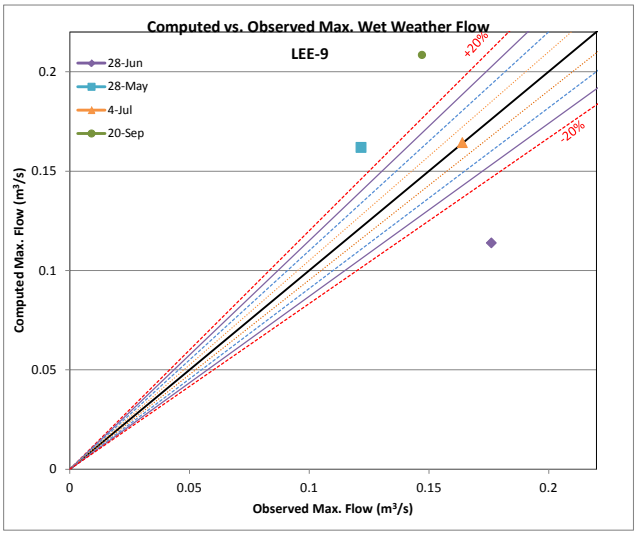
GLN-4

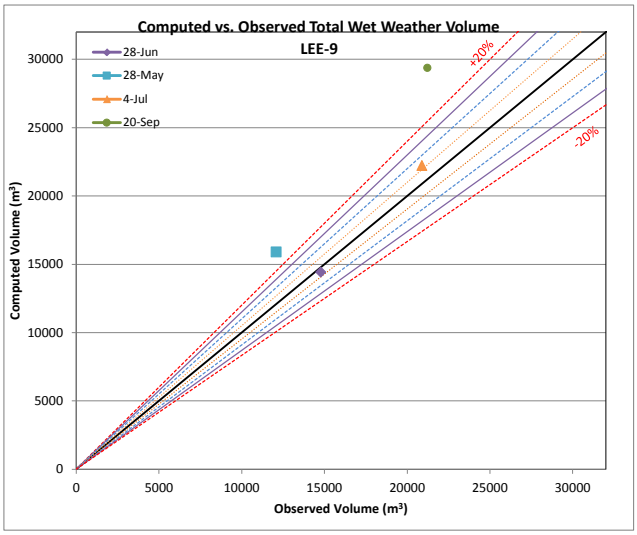




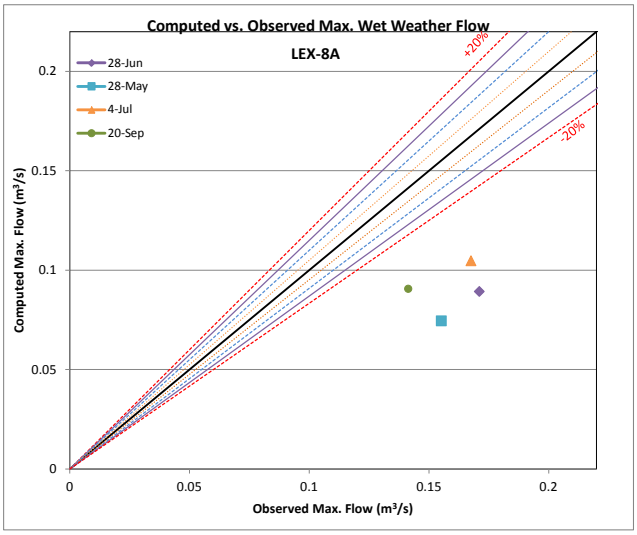
1611-11191: Waterloo Master Plan Update
Wet Weather Flow Calibration/Validation Plots

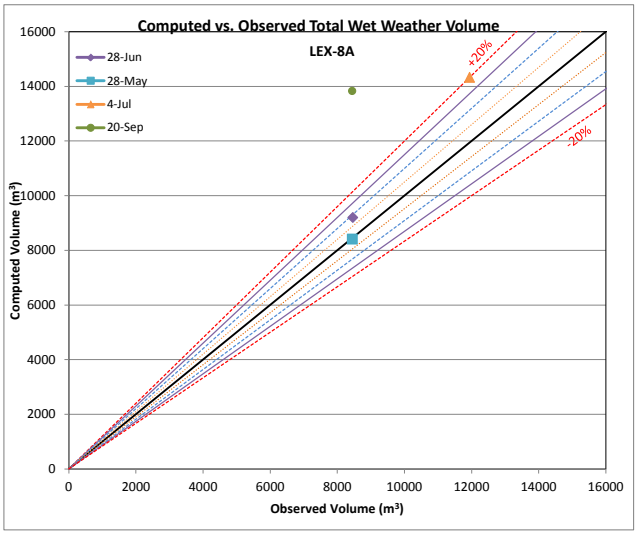
LEE-9



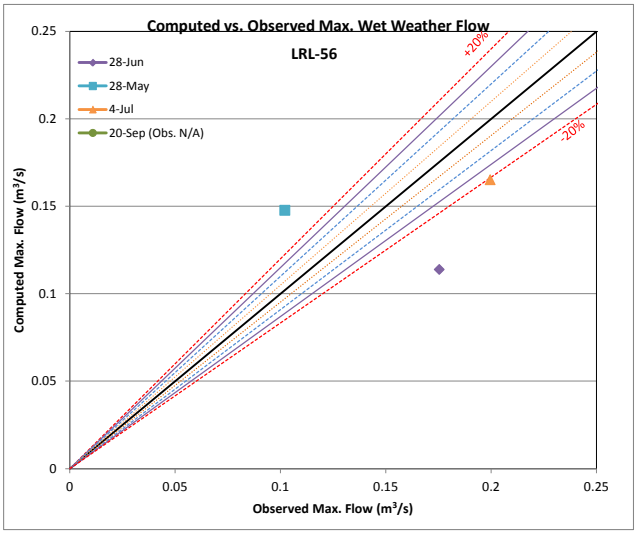


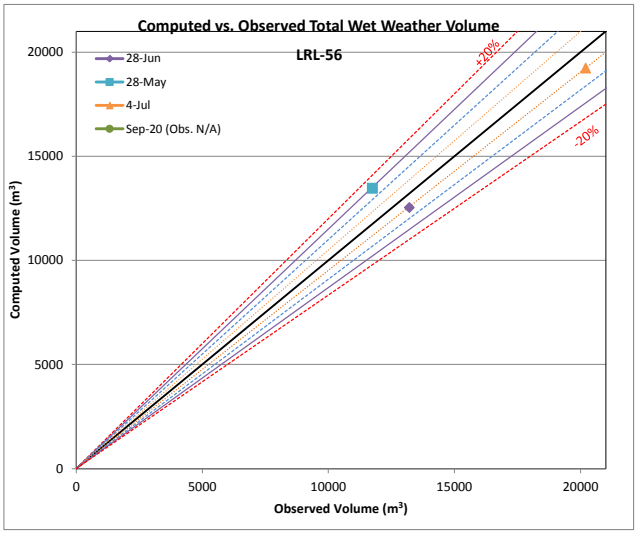
LEX-8A





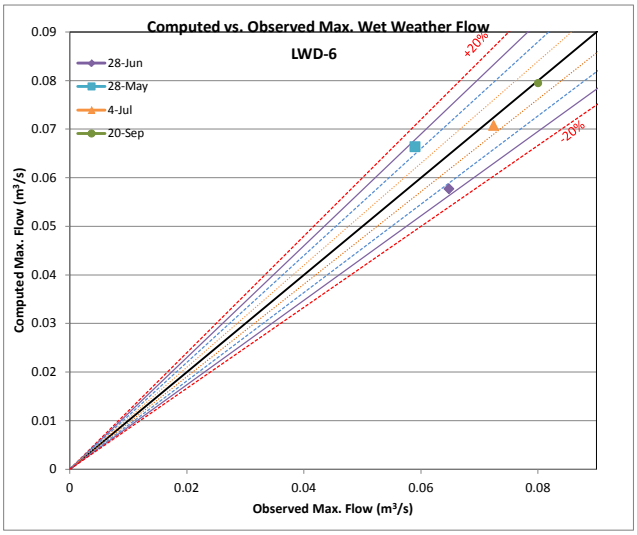
LRL-56

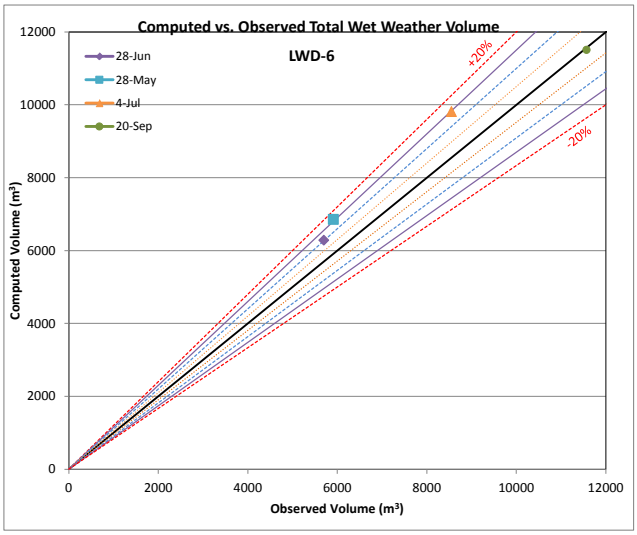




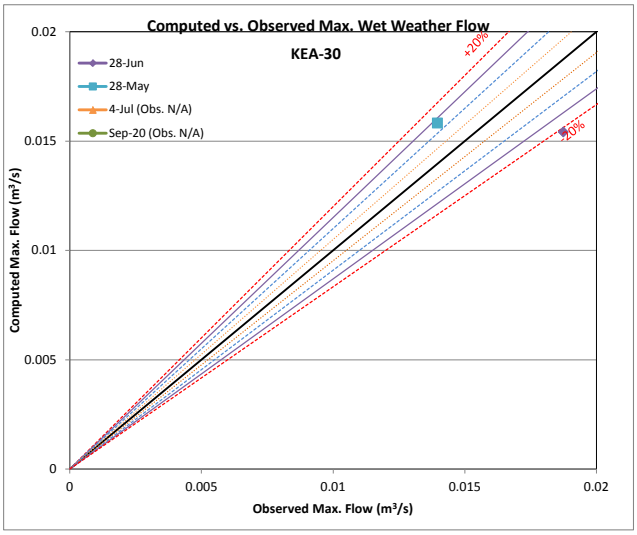
1611-11191: Waterloo Master Plan Update
Wet Weather Flow Calibration/Validation Plots

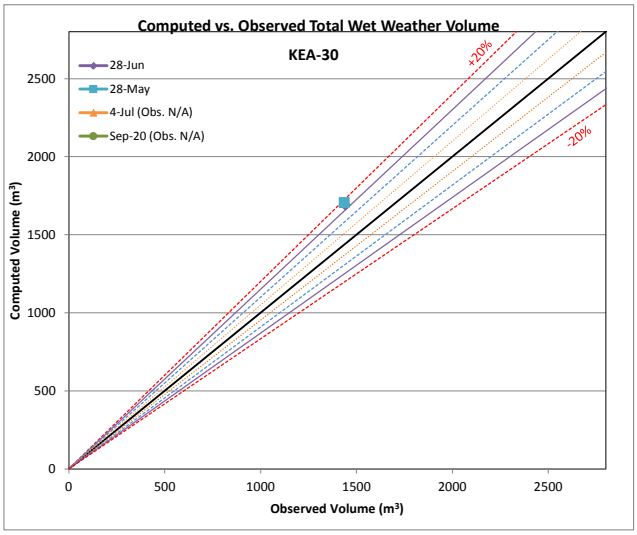
LWD-6



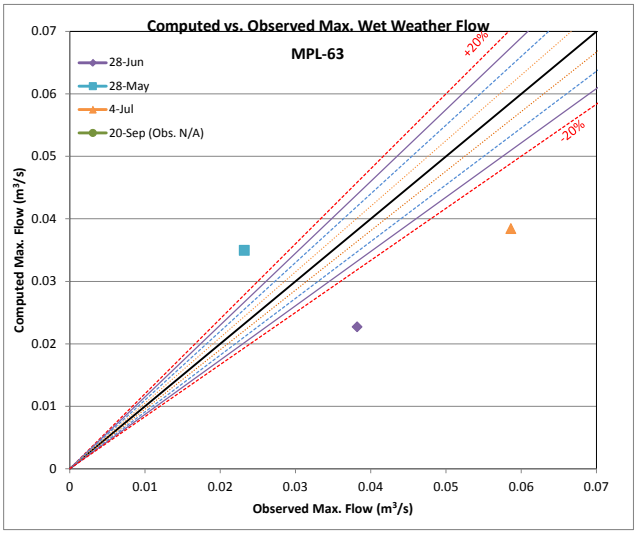


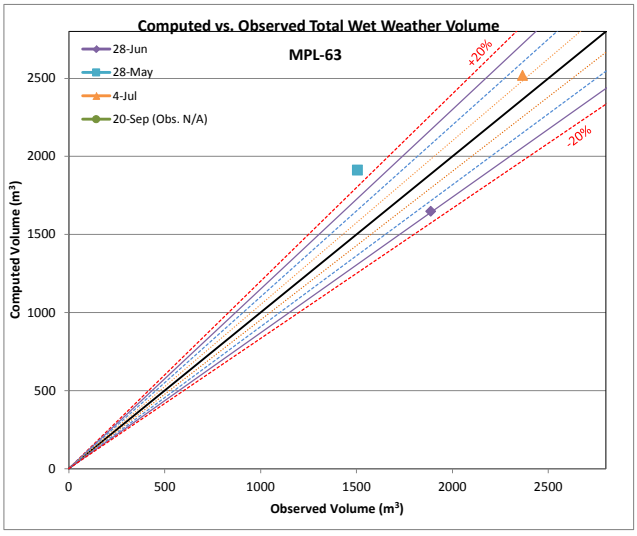
KEA-30





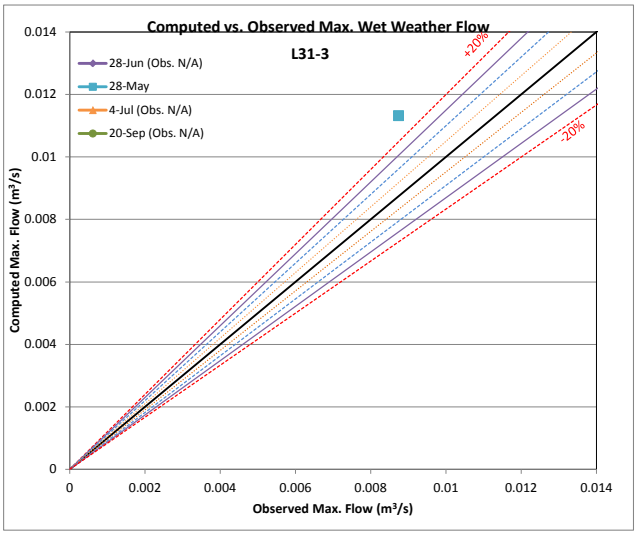
MPL-63

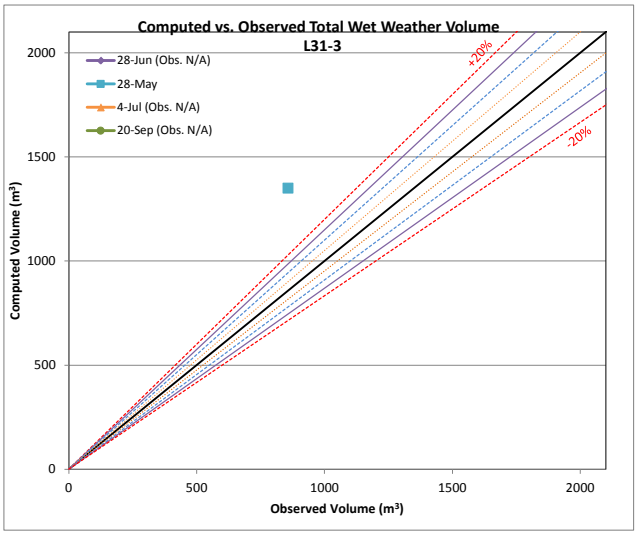




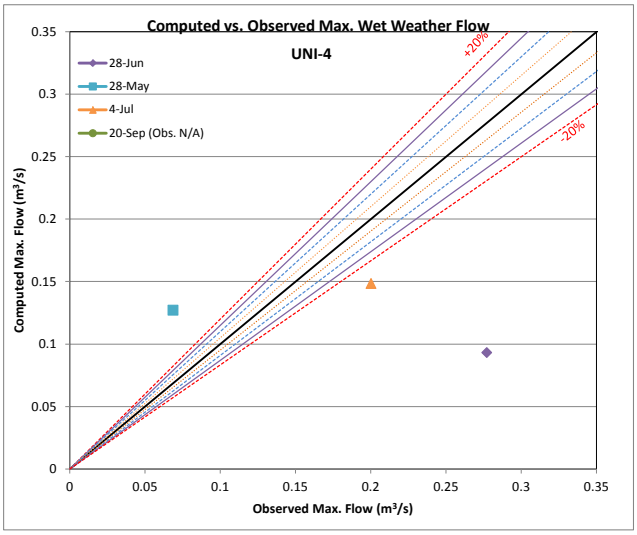
1611-11191: Waterloo Master Plan Update
Wet Weather Flow Calibration/Validation Plots

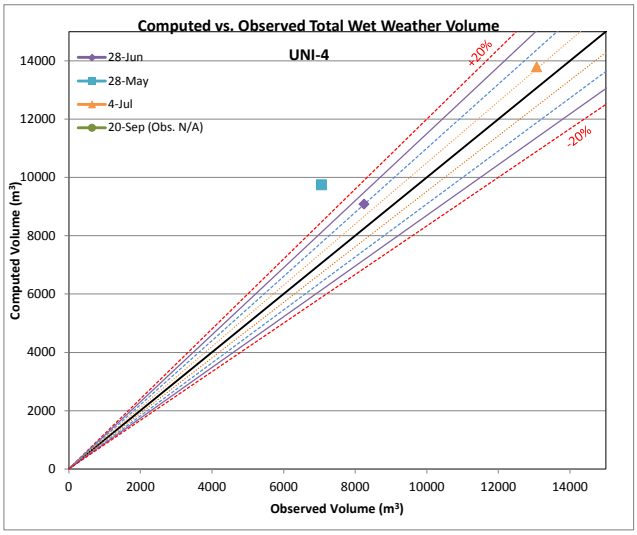
L31-3



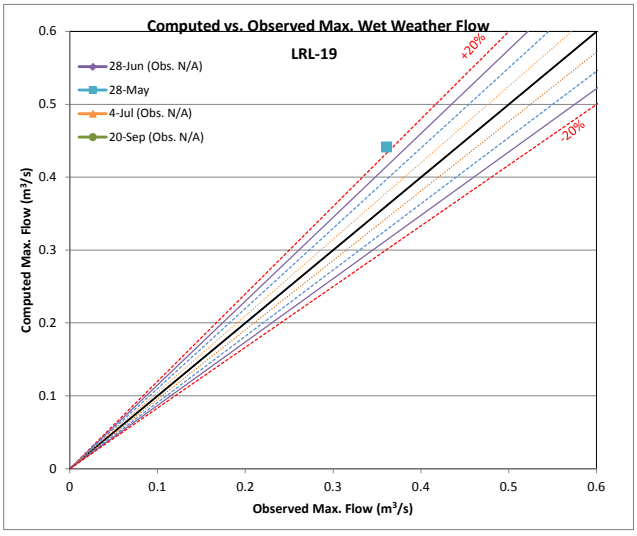


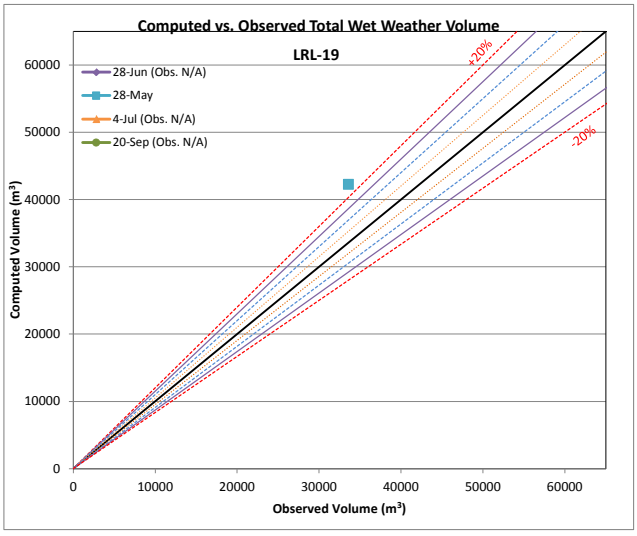
UNI-4





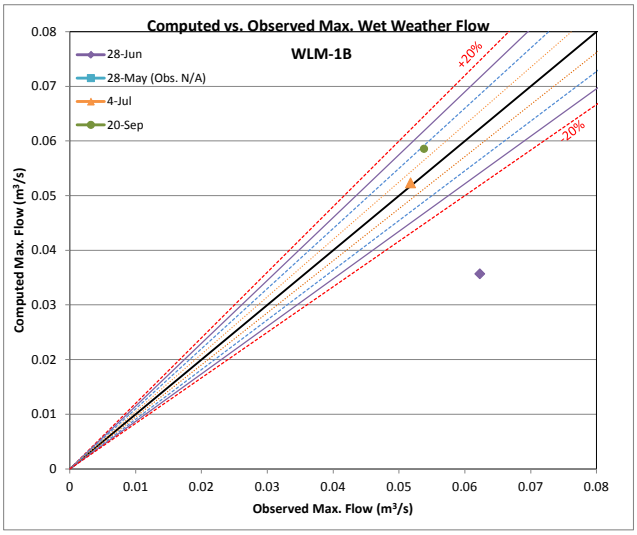
LRL-19

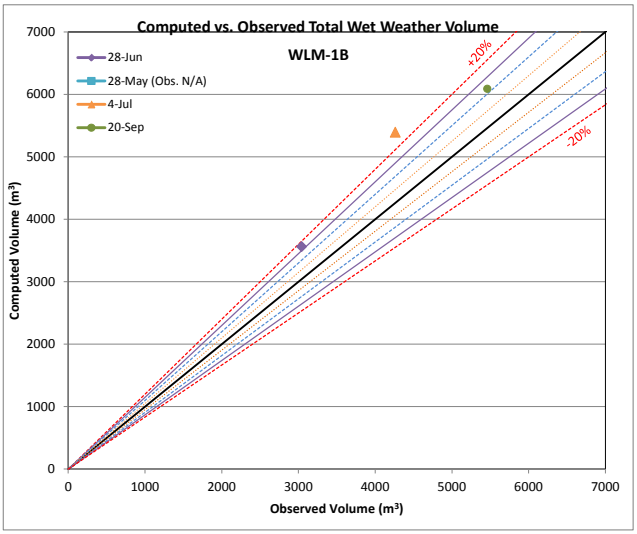




1611-11191: Waterloo Master Plan Update
Wet Weather Flow Calibration/Validation Plots

WLM-1B





Appendix C TOWNSHIP OF WOOLWICH INFLOWS

Hale, Jennifer

From: Eadie, Dave
Sent: Thursday, March 13, 2014 1:57 PM
To: Hale, Jennifer
Cc: Sapeta, Nicole; McDermott, Leigh
Subject: Woolwich SAN Service Area
Attachments: Countryside 1994 General Layout Sanitary Sewer Design Areas 03.tif; ATT04343.pdf; ATT91576.pdf; SW-SND.PDF

Follow Up Flag: Follow up
Flag Status: Completed

Hey Jen – what can you make out of the attached re: Woolwich service area?

From: Randy Miller [mailto:rmiller@woolwich.ca]
Sent: Thursday, March 13, 2014 1:52 PM
To: Eadie, Dave
Cc: Jakub Cyperling; John Scarfone
Subject: RE: Wat. Sani. MP - Laurel Trunk

Hi Dave,

I have attached a plan that shows the settlement boundary for the Stockyards with the purple areas designated C6 (King & 86 Smart Centres lands) and the areas in grey designated C8. Some of the designated C8 lands located north of King Street and west of Weber Street including the east side of HWY 85 are not currently serviced but are in the designated boundary area is included in the upcoming secondary plan for this settlement area. Also attached is a copy of the sanitary drainage plan for the west end of Farmers Market Road and Benjamin Road which outlets to the City via Conrad Place. As you have noted the stockyard property located at 878 Weber Street North (original stockyard property) has a private lift station which outlets to Farmers Market Road at Benjamin Road. The King & 86 development (Smart Centres) located at 330 and 335 Farmers Market road outlets to the City via Kumpf Drive (see attached sanitary drainage plan). Drainage Areas 2 & 5 are complete and Area 1 will be completed this summer. Drainage Areas 4 & 5 is a future Phase which will require a new SP (not sure what the timing is for this area).

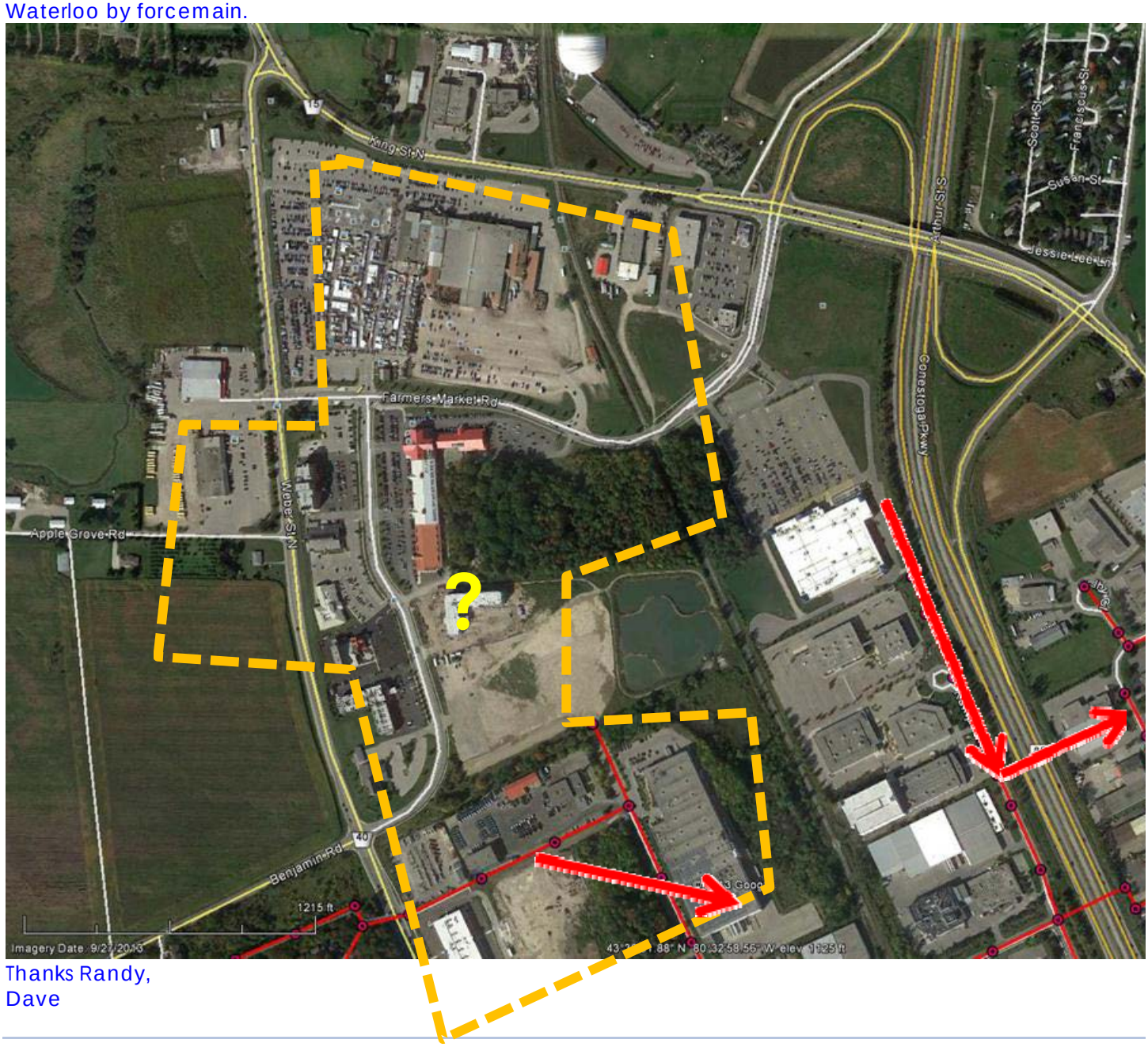
Regards

Randy Miller
Development Engineering Supervisor
Engineering and Planning Services
Direct Dial 519-669-6030
Fax 519-669-4669

From: Eadie, Dave [mailto:Dave.Eadie@stantec.com]
Sent: Tuesday, February 25, 2014 11:18 AM
To: Randy Miller
Subject: RE: Wat. Sani. MP - Laurel Trunk

Thanks Randy – found the memo, but we are lacking in maps of this area to put it into further context. Does the Township have drawings (plan/profile)/infrastructure or sanitary drainage area maps for this area draining to Waterloo? Trying to confirm service area (see below). I take it from the information I could dig up that there was a manhole behind the Walmart that received flows from upstream plaza as well (overall SmartCentre). Do

you know what remaining buildings there are to come on line? I understand the Farmers Market reaches Waterloo by forcemain.



Thanks Randy,
Dave

From: Randy Miller [mailto:rmiller@woolwich.ca]
Sent: Friday, February 21, 2014 4:35 PM
To: Eadie, Dave
Subject: RE: Wat. Sani. MP - Laurel Trunk

Hi Dave, I am not sure what the MH location is. All I found was a memo referencing a memo that Barbara sent to John Scarfone in our office sometime early 2012. From what I gather this monitoring was to get a sense as to what type of flows a Walmart generates to help us understand what the Smart Centres Breslau site might generate.

Randy Miller
Development Engineering Supervisor
Engineering and Planning Services
Direct Dial 519-669-6030
Fax 519-669-4669

From: Eadie, Dave [mailto:Dave.Eadie@stantec.com]
Sent: Friday, February 21, 2014 4:23 PM
To: Randy Miller
Subject: FW: Wat. Sani. MP - Laurel Trunk

Hi Randy – hope all is well. Regarding Jakub's message below, are you referring to the Walmart (MH87) monitor?
Thanks,
Dave

From: Jakub Cyperling [mailto:Jakub.Cyperling@waterloo.ca]
Sent: Friday, February 21, 2014 4:07 PM
To: Eadie, Dave
Cc: Jeff Little
Subject: RE: Wat. Sani. MP - Laurel Trunk

Hey Dave,

I was informed that Stantec, namely you and Barb Robinson were managing flow monitoring initiatives for the township of Woolwich at the time. Randy Miller advised that they had a monitor on the Power Centre from May 2011 to January 2012. Can you please check what you have internally and get back to me, I have some rough notes that Randy passed along as well. He mentioned a synopsis noted peak observed flow in October of 2011 to be 2.77 L/s and normal peak flow of 1.7 L/s approximately.

Regards,

Jakub Cyperling, C.E.T.

From: Eadie, Dave [mailto:Dave.Eadie@stantec.com]
Sent: Friday, February 21, 2014 3:35 PM
To: Jakub Cyperling
Cc: Jeff Little; Sapeta, Nicole; Hale, Jennifer
Subject: RE: Wat. Sani. MP - Laurel Trunk

Thanks for the clarification. We will assume 1200mm unless there is objection from Jeff, or new information that is revealed telling us otherwise.
In all future correspondence and reporting, we will refer to both MXASSETID and former ENTNAME for MH's, to allow easier reference. There were some duplicate or missing 'old' names, requiring the use of MXASSETID's for MH's since new (and future) MH's don't use the old convention. Both IDs will be in the geodatabase and the model for reference.
Have a good weekend,
Dave

From: Jakub Cyperling [mailto:Jakub.Cyperling@waterloo.ca]
Sent: Friday, February 21, 2014 3:20 PM
To: Eadie, Dave
Cc: Jeff Little
Subject: RE: Wat. Sani. MP - Laurel Trunk

Hey Dave,

I do note that this is the correct infrastructure size according to the video inspection records although I'm not sure I agree with the process used to obtain diameters for this particular inspection. I was informed that the dimensions from the video inspection record were not actually physically measured, this is essentially an estimate, my feeling is that we should indicate these as 1200mm Dia. pipes, this is what was in the as-built information. I have the videos and have posted them to SharePoint under Background Information, they look like 1200's to me, the access MH's **should** be 1200mm Dia. in size and appear to be coincidental with the size of the pipe, not saying they are. 0.9m would be a little bit tight for access if you ask me.

There was no work complete on the Laurel Trunk sewer through this section, this is likely going to be the "bottleneck" section within the Laurel Trunk sewer. The Laurel Trunk has been twinned upstream of Peppler Street and downstream of Marshall Street.

Noted from your figure below, I would like to see the City MH nomenclature used within all aspects of the MP work, i.e.. LRL-22, can we do this in parallel with MXASSID or in place of? It makes it really difficult to follow along if it is not there for reference, could care less about links. Not sure why it is an issue for the MH's or if it is at all if we are only doing this for the MH's? There shouldn't be any duplicates in this or issues with import that I can note from Autodesk SSA software. Please indicate how we can work around this.

Still trying to track down the rest of the outstanding SPS information, we can touch base on this next week. I have requested and am waiting on a flow monitoring report from the Woolwich Power Centre. Still waiting on word back relating to the ***CofW_DA_Pop_HH.shp*** shape file, this data is from the 2011 census and would have been provided from Stats Canada.

Regards,

Jakub Cyperling, C.E.T.
PM & Project Designer, Engineering
Integrated Planning and
Public Works, City of Waterloo
265 Lexington Court
PO Box 337, Station Waterloo
Waterloo, ON, N2J 4A8
P: 519-747-8604
TTY: 1-866-786-3941
E: Jakub.Cyperling@Waterloo.ca
www.waterloo.ca

THE CITY OF Waterloo

From: Eadie, Dave [mailto:Dave.Eadie@stantec.com]
Sent: Friday, February 21, 2014 12:13 PM
To: Jakub Cyperling
Subject: FW: Wat. Sani. MP - Laurel Trunk

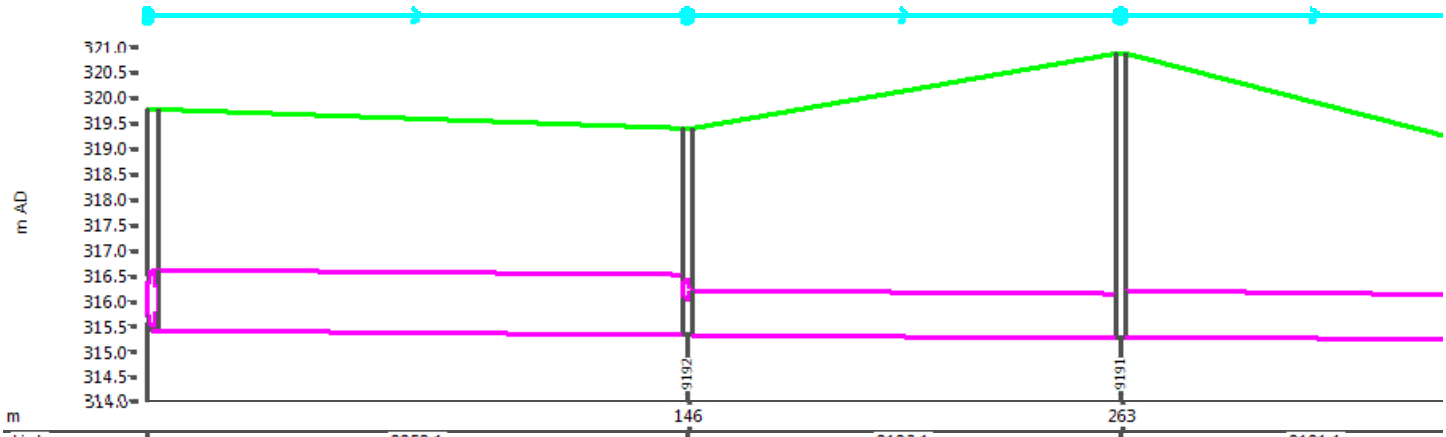
Jakub – see the message below. Effectively what we are trying to resolve is the status and extent (as of end 2013) of the Laurel Trunk upgrades.
Regards,
Dave

From: Hale, Jennifer
Sent: Friday, February 21, 2014 11:31 AM
To: Eadie, Dave
Subject: Wat. Sani. MP - Laurel Trunk

Dave,

As discussed:

During the review of the Geodatabase provided to Stantec January 31, 2014, some question was raised regarding diameters on the Laurel Trunk. The Laurel Trunk running from Weber Street to University Ave and Carter Ave is mostly a 1200 mm diameter main. However, there are four conduits (listed below) which are 900 mm diameter. This is curious because the conduits upstream and downstream of these four pipes are 1200 mm, and in the previous Geodatabase that Stantec provided to the City before the New Year had these pipes listed as a 1200. We just want to confirm the diameter of these conduits.



Link	9958.1	9192.1	9191.1
length (m)	145.9	117.0	105.3
Shape ID	CIRC	CIRC	CIRC
width (mm)	1200	900	900
height (mm)	1200	900	900
us inv (m AD)	315.430	315.320	315.313
ds inv (m AD)	315.320	315.260	315.229
grad (m/m)	0.00075	0.00051	0.00080
pfc (m3/s)			
Node	9958	9192	9191
ground (m AD)	319.800	319.407	320.888

MXASSETNUM: 3921 ENTNAME: LRL-23toLRL-22
MXASSETNUM: 3922 ENTNAME: LRL-22toLRL-21
MXASSETNUM: 3909 ENTNAME: LRL-21toLRL-20
MXASSETNUM: 3923 ENTNAME: LRL-20toLRL-19

Thanks,

Jennifer Hale, B.A.Sc.
Engineering Intern, EIT
Stantec
49 Frederick Street Kitchener ON N2H 6M7
Phone: (519) 585-7362
Cell: (519) 498-0947
Fax: (519) 579-6733
Jennifer.Hale@stantec.com

Stantec

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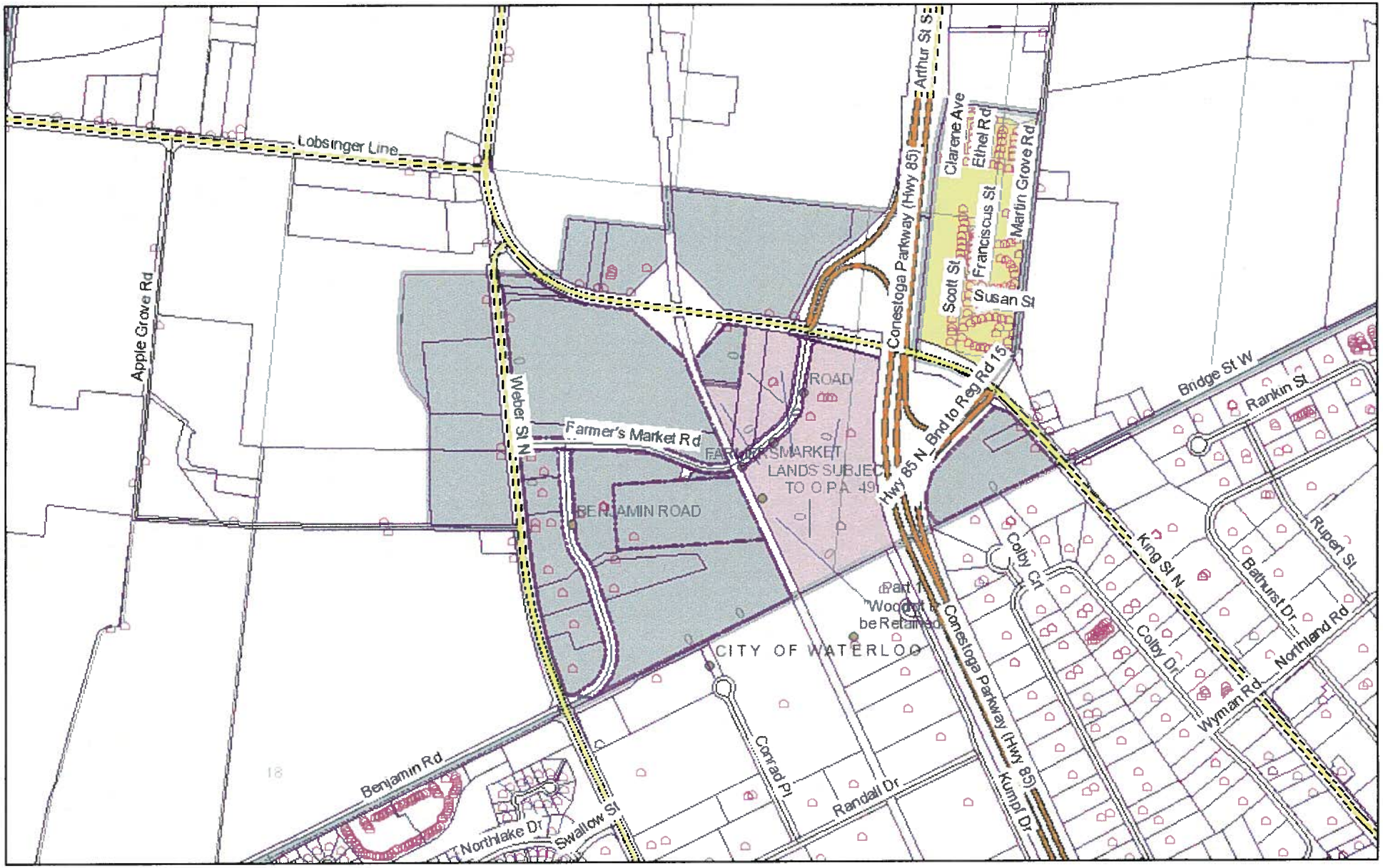
St. Jacobs Stockyard



March 12, 2014

1:11,577

0 0.1 0.2 0.4 mi

0 0.15 0.3 0.6 km

- Brant; Hamilton-Wentworth; Oxford; Perth; Region of Waterloo
- Wellington
- Ontario
- Local
- Private
- Future Roads
- Address

BENJAMIN ROAD

TWP. ROAD 39

REGIONAL ROAD NO. 8 (Weber St. N)

EXISTING PAVEMENT

N 05° 13' 10" W

R=1149.01

N 13° 48' 15" W

CH=342.82

A=344.10

N 64° 36' 10" E

BENJAMIN ROAD

1.35ha 0.000225 m³/s

1.30ha 0.000225 m³/s

0.92ha 0.000225 m³/s

1.27ha 0.000225 m³/s

0.85ha 0.000225 m³/s

4.47ha 0.000225 m³/s

3.55ha 0.000225 m³/s

4.06ha 0.000225 m³/s

4.21ha 0.000225 m³/s

15.4m 150mmø DR28 PVC SERVICE CONNECTION @ 1.00% ø EX SAN MH

13.2m 150mmø DR28 P.V.C. SERVICE CONNECTION @ 1.00%

17.6m 150mmø DR28 P.V.C. SERVICE CONNECTION @ 1.00%

13.2m 150mmø DR28 P.V.C. SERVICE CONNECTION @ 1.00%

14.6m 150mmø DR28 P.V.C. SERVICE CONNECTION @ 1.00%

13.8m 150mmø DR28 P.V.C. SERVICE CONNECTION @ 1.00%

89.8m 200mmø DR35 P.V.C. SAN SEWER @ 0.36% MH4A

78.0m 200mmø DR35 P.V.C. SAN SEWER @ 0.38% MH3A

67.0m 200mmø DR35 PVC SAN. @ 0.35% MH2A

47.5m 200mmø DR35 P.V.C. SANITARY SEWER @ 0.33% MH1A

93.2m 200mmø DR35 P.V.C. SANITARY SEWER @ 0.31% MH5

69.3m 200mmø DR35 P.V.C. SAN SEWER @ 0.31%

SANITARY SEWER INSTALLED BY OTHERS FOR DETAILS SEE DRAWING No. 1030-05, CONTRACT No. 930810

6.0m EASEMENT

N 02° 38' 20" W

140.61

N 87° 16' 10" E

N 15° 20' 30" E

70.95

N 87° 14' 50" E

121.92

N 64° 36' 10" E

171.39

N64°35'00"E

10.85

N 64° 35' 00" E

20.12

N64°35'00"E

EXISTING 20.117 EASEMENT

EXISTING 1.0% SAN.SEWER MH

119.0m 200mmø DR35 P.V.C. SANITARY SEWER @ 0.32%

CONRAD PLACE

STORMWATER MANAGEMENT AREA

EASEMENT

FORWELL CREEK

203.72

246.70

187.66

N 23° 49' 00" W

CANADIAN NATIONAL RAILWAY

FARMER'S MARKET ROAD

275.87

N 04° 43' 50" W

255.70

20.70

N42°32'15"E

85.33

N89°46'50"E

176.17

N 80° 46' 50" W

152.04

HIGHWAY NO. 85 (King Street N)

N 46° 42' 30" W

N 19° 56' 44" W

CH=118.95

A=119.04

R=883.29

263.44

187.66

N 23° 49' 00" W

10.1m 200mmø P.V.C. SANITARY SEWER @ 0.50% WITH PLUG

MH1.2A

16.7m 200mmø P.V.C. SANITARY SEWER @ 0.50% WITH PLUG

FUTURE KUMPF DRIVE

REG. ROAD No.15 (KING ST.)

AREA OF CATCHMENT — 1.55ha 0.000225 m³/s

DESIGN FLOW PER HECTARE

NOTE: INFILTRATION ALLOWANCE OF 0.00015m3/s/ha WAS ADDED.

NO.	DESCRIPTION	DATE	INTL.
4	AS-CONSTRUCTED	26-01-94	FEDZ
3	REV SAN STUB SIZE, ADDED NOTE	01-08-91	RCB
2	REV INTERSECTION OF FARMER'S MARKET RD @ KING ST	23-07-91	RCB
1	REV SEWER SIZES,ADD EASEMENT, PT 3, & KUMPF DR	09-04-91	RCB

LICENSED PROFESSIONAL ENGINEER K. J. BOUDREAU PROVINCE OF ONTARIO

CHECKED: APPROVED:

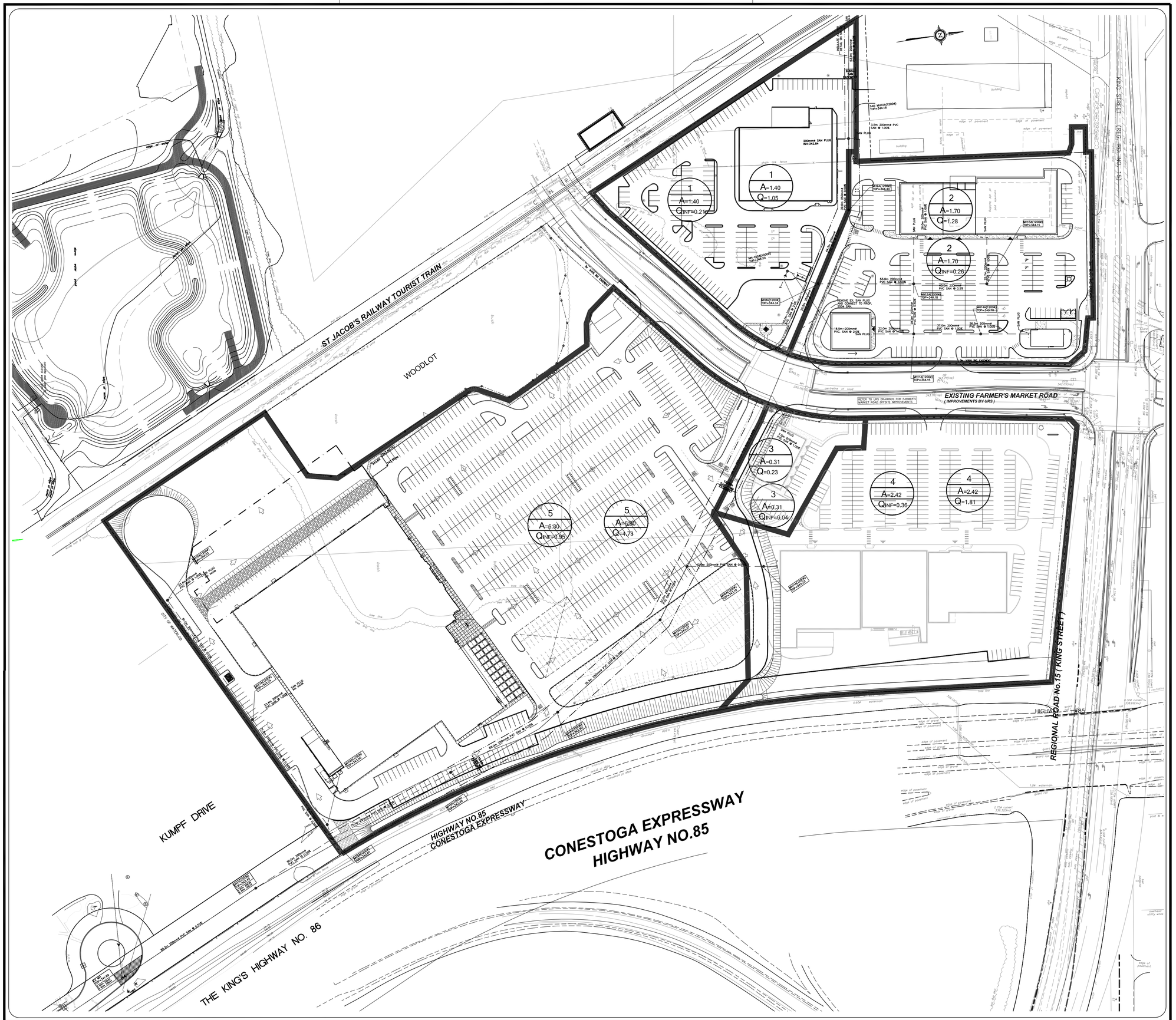
COUNTRYSIDE
MERCEDES CORPORATION
TOWNSHIP OF WOOLWICH

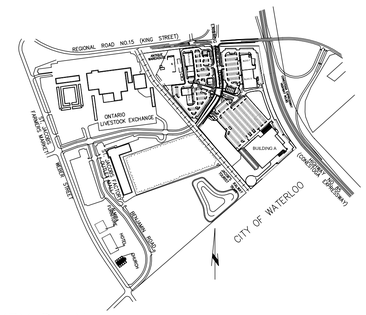
WRIGHT-DIETRICH PLANNERS,ENGINEERS, & LAND DEVELOPMENT CONSULTANTS

GENERAL LAYOUT

SANITARY SEWER DESIGN AREAS

DRAWN BY:	RCB,FEDZ	SCALE: 1:1250	DWG. NO.: 03
DESIGN BY:	RCB		
CHECKED BY:	PJW/MJKJB	DATE: 15-02-1991	





KEY PLAN

GENERAL NOTES

1. ALL WORK SHALL BE CARRIED OUT IN COMPLIANCE WITH THE APPLICABLE HEALTH AND SAFETY ACT AND REGULATIONS FOR CONSTRUCTION PROJECTS.
2. ALL WORK AND MATERIALS TO CONFORM WITH THE MINISTRY OF ENVIRONMENT, REGIONAL MUNICIPALITY OF WATERLOO, TOWNSHIP OF WOOLWICH, ONTARIO, PROVINCIAL STANDARDS AND SPECIFICATIONS, LOCAL UTILITY STANDARDS AND MINISTRY OF TRANSPORTATION STANDARDS.
3. THE CONTRACTOR IS ADVISED THAT WORKS BY OTHERS MAY BE ONGOING DURING THE PERIOD OF THIS CONTRACT. THE CONTRACTOR SHALL COORDINATE CONSTRUCTION ACTIVITIES WITH ALL OTHER CONTRACTORS AND PREVENT CONSTRUCTION CONFLICTS.
4. THE INFORMATION SHOWN FOR EXISTING UTILITIES WAS PROVIDED BY OTHERS. CONTRACTOR IS RESPONSIBLE FOR LOCATING AND PROTECTING ALL UTILITIES DURING CONSTRUCTION. ALL EXISTING UTILITIES MUST BE LOCATED AND VERIFIED BY EACH UTILITY PRIOR TO COMMENCEMENT OF WORK. ANY VARIANCE IS TO BE IMMEDIATELY REPORTED TO THE ENGINEER. LOST TIME DUE TO FAILURE OF THE CONTRACTOR TO CONFIRM UTILITY LOCATIONS AND NOTIFY THE ENGINEER OF POSSIBLE CONFLICTS PRIOR TO CONSTRUCTION WILL BE AT THE CONTRACTORS EXPENSE.
5. INSPECTIONS:
   ALL WORK ON THE MUNICIPAL RIGHT OF WAY AND EASEMENTS TO BE INSPECTED BY THE MUNICIPALITY PRIOR TO BACKFILLING. ALL WORK RELATING TO WATERMAINS AND SEWERS TO BE INSPECTED BY THE MUNICIPALITY WHEN REQUIRED BY THE SITE PLAN AGREEMENT.
6. PRIOR TO INSTALLATION OF STRUCTURE FOUNDATIONS, UNDERLAIN SOILS SHALL BE INSPECTED AND APPROVED BY THE GEOTECHNICAL ENGINEER. SHOULD SOILS BE DEEMED UNSUITABLE, MEASURES SHALL BE TAKEN BY THE CONTRACTOR AS PER GEOTECHNICAL ENGINEER'S RECOMMENDATIONS.
7. ALL LANDSCAPING, PLANTING, SLOPE VEGETATION, AND FENCING AS PER APPROVED LANDSCAPE DRAWINGS.
8. ALL WORKS WITH IN THE RIGHT-OF-WAY OR CITY EASEMENTS ARE TO BE INSTALLED TO THE TOWNSHIP OF WOOLWICH SATISFACTION.

LEGAL & TOPOGRAPHY

PROVIDED BY:

ACI SURVEY CONSULTANTS
ONTARIO LAND SURVEYORS
592 FREDERICK ST, KITCHENER, ON T: 519-578-2220 F: 519-578-9644
39 ENGLISH PLACE, CAMBRIDGE, ON T: 519-622-3477 F: 519-622-4060
www.landsurveyor.ca

BENCHMARK

NOTE:
ELEVATIONS HEREON ARE DERIVED FROM GEODETIC DATUM AND ARE REFERRED TO THE REGIONAL MUNICIPALITY OF WATERLOO PRECISE BENCH MARK No. 65-200, ELEVATION 342.644 m.

LEGEND

- STORM MANHOLE
- STORM SEWER
- DRAINAGE BOUNDARY

4 / A=2.42 / Q=1.81 — AREA ID NUMBER, DRAINAGE AREA (ha), FLOW (L/s)

4 / A=2.42 / QINF=0.36 — AREA ID NUMBER, DRAINAGE AREA (ha), INFILTRATION (L/s)

No.	REVISIONS/ISSUED	DATE	BY	CITY
2	RE-ISSUED FOR CITY OF WATERLOO REVIEW - BLDG B	MAR 13/14		
1	ISSUED FOR CITY OF WATERLOO REVIEW	JAN 15/08		

ENGINEERS STAMP

counterpoint ENGINEERING
COUNTERPOINT ENGINEERING INC.
8305 Jane St., Suite 100, Vaughan, ON L4K 5Y2 Phone 905.326.1404 Fax 905.326.1405

APPLICANT:
KING/86 DEVELOPMENTS LTD.
700 APPLEWOOD CRES
SUITE 100
VAUGHAN, ON
L4K 5X3

SITE LOCATION:
KING/86 COMMERCIAL DEVELOPMENT

TOWNSHIP OF WOOLWICH
SITE PLAN FILE No.: SP1\2003

SANITARY DRAINAGE PLAN

DESIGNED BY: M.B	CHECKED BY: M.B	DATE: MARCH 2014
DRAWING BY: C.B	CHECKED BY:	PROJECT No. 13083
SWM BY:	CHECKED BY:	
SCALE: 1:1000		DRAWING No. SW-SND

Appendix D SANITARY RECALIBRATION AND VALIDATION OF FORWELL TRUNK

1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-002 FWL-4A

Conduit: 3928

Diameter: 825 mm

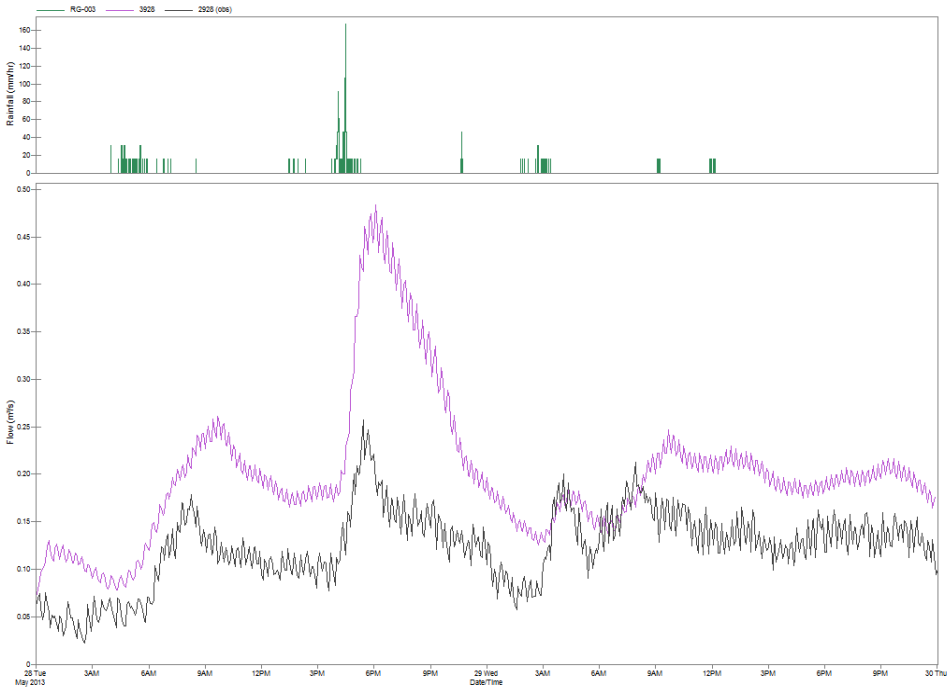
Model Input Parameters

Parameter	1	2	3
R	0.025	0.005	0.001
T	0.21	12.00	24.00
K	28	5	4

R_{total} 3.1%

May 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4b.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
5/28/2013 0:00	47.99	40.64	167.6	0.257	0.484	0.124	0.201	21360	34680
Difference (%)					88%		62%		62%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

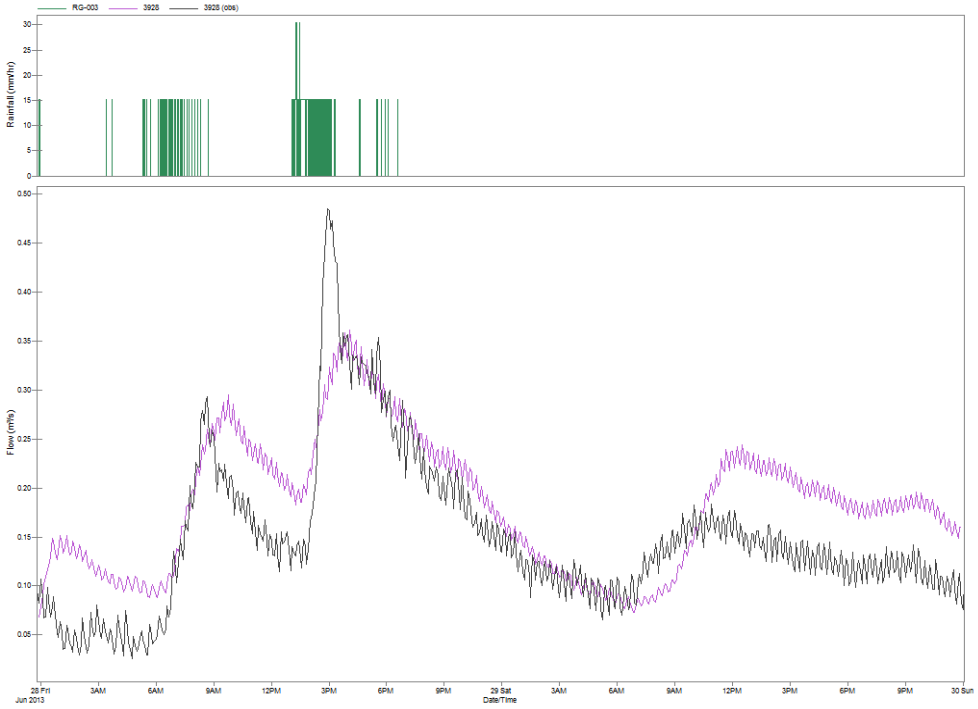
Monitor: FM-002 FWL-4A

Conduit: 3928

Diameter: 825 mm

June 28, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4c.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
6/27/2013 23:58	48.04	27.18	30.48	0.485	0.362	0.150	0.183	25910	31650
Difference (%)					-26%		22%		22%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

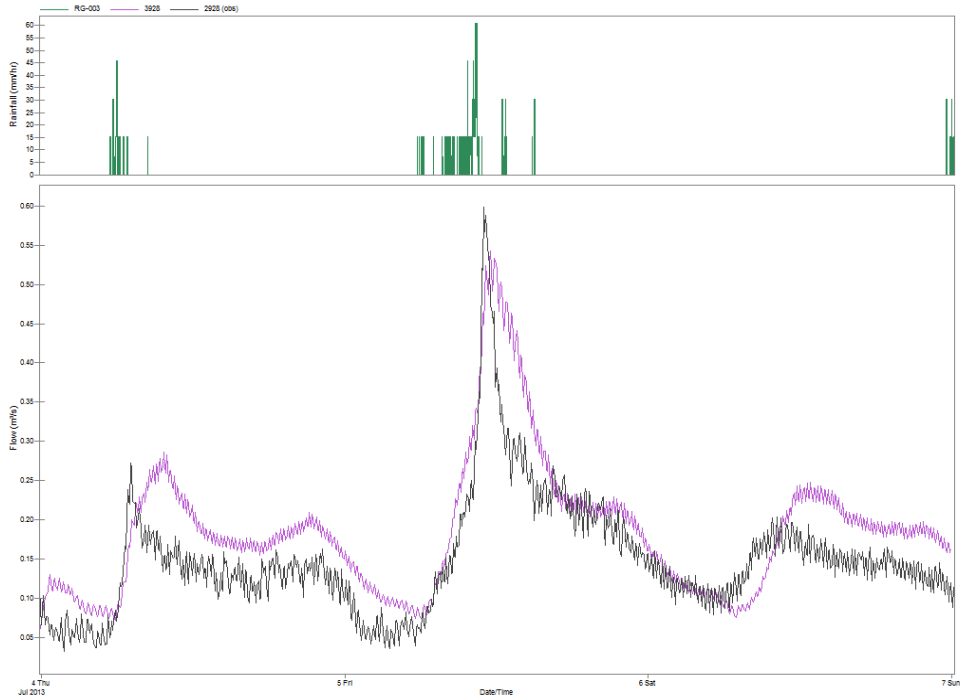
Monitor: FM-002 FWL-4A

Conduit: 3928

Diameter: 825 mm

July 5, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4a.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
7/3/2013 23:53	72	33.78	60.96	0.599	0.542	0.150	0.186	38800	48230
Difference (%)					-9%		25%		24%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

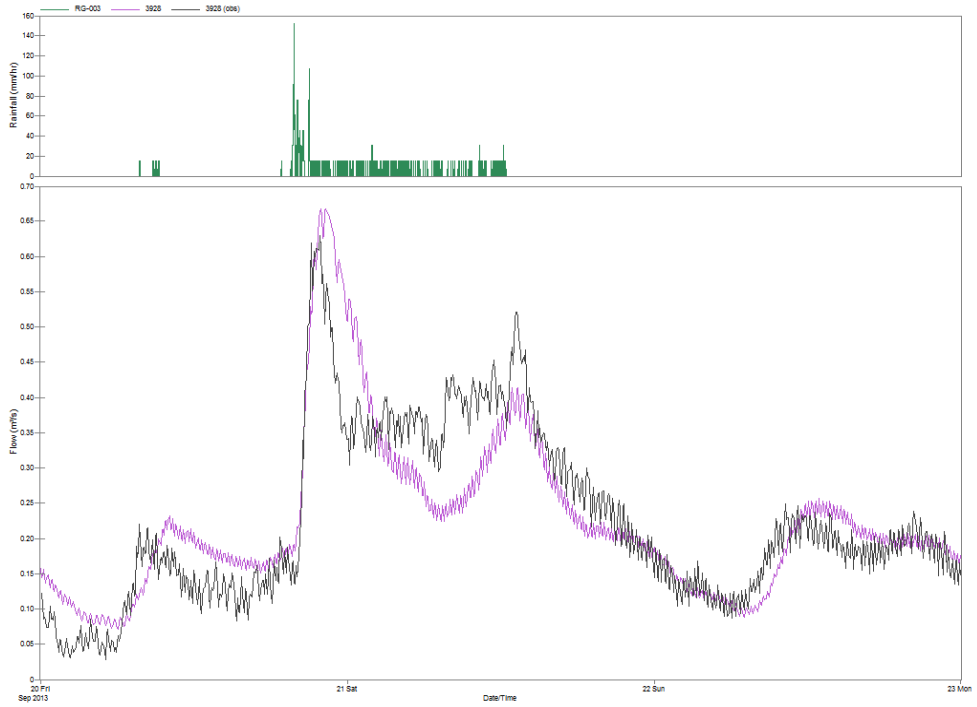
Monitor: FM-002 FWL-4A

Conduit: 3928

Diameter: 825 mm

September 20, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Trial4d.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
9/19/2013 23:56	72	90.17	152.4	0.630	0.667	0.226	0.226	58470	58440
Difference (%)					6%		0%		0%



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

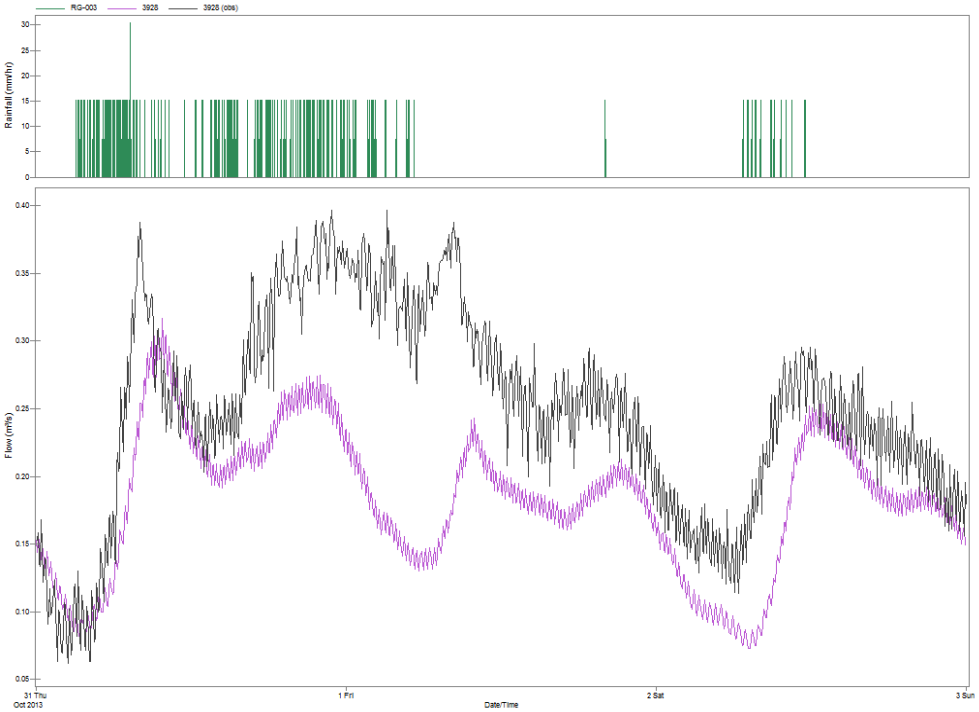
Monitor: FM-002 FWL-4A

Conduit: 3928

Diameter: 825 mm

October 30, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Oct31-Nov2_2013.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
10/30/2013 23:54	72.24	42.42	30.48	0.3968	0.3167	0.2493	0.1822	64540	47230
Difference (%)					-20%		-27%		-27%



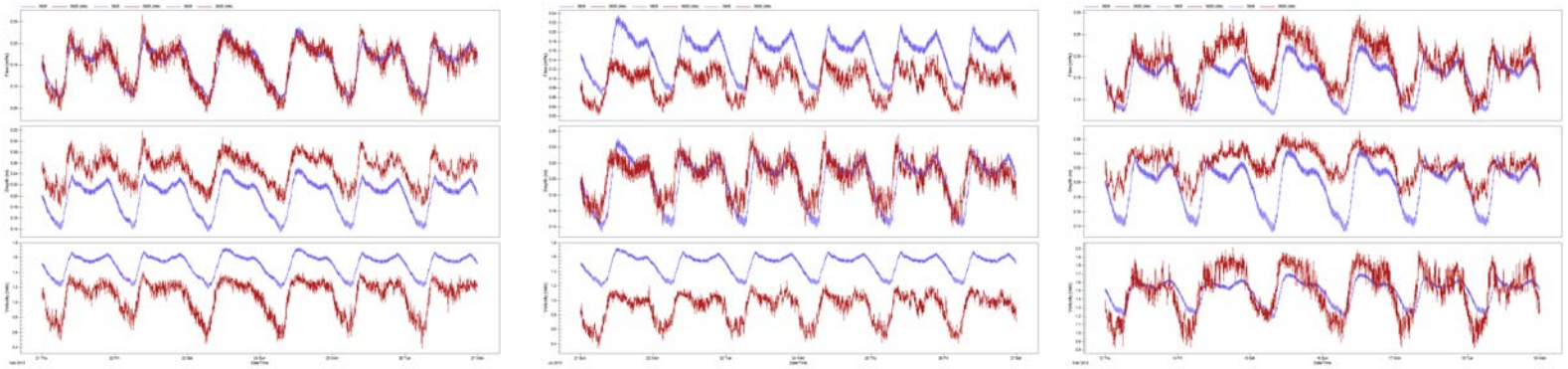
1611-11191: Waterloo Sanitary Master Plan
Dry Weather Calibration - Final

Monitor: FM-002 FWL-4A
Conduit: 3928

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event 1				Validation Event 2			
Date	Date	November 21-26, 2013			July 21-26, 2013				March 13-18, 2014			
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.019	0.019			0.019	0.019			0.019	0.019		
Base Flow (L/s)	6.48	6.37			6.48	6.37			6.48	6.37		
Population	18631	18622			18631	18622			18631	18622		
Per Capita (L/c/d)	312	312			312	312			312	312		
Avg. Sewage (L/s)	67.3	67.3			67.3	67.3			67.3	67.3		
Pipe (mm)	825	825			825	825			825	825		
Total Area (ha)	886.0	886.0			886.0	886.0			886.0	886.0		
Incremental Area (ha)	339.6	333.7			339.6	333.7			339.6	333.7		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.319	0.252	-0.067	-21%	0.261	0.250	-0.010	-4%	0.272	0.247	-0.025	-9%
Q_{max} (m^3/s)	0.265	0.238	-0.027	-10%	0.173	0.237	0.063	37%	0.295	0.230	-0.065	-22%
Vol (m^3)	78187	79493	1306	2%	49457	78568	29111	59%	93398	77690	-15708	-17%
Vel_{max} (m/s)	1.4	1.7	0.3	23%	1.3	1.7	0.5	36%	2.0	1.7	-0.3	-15%

Graph



1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-014 FWL-22

Conduit: 5556

Diameter: 600 mm

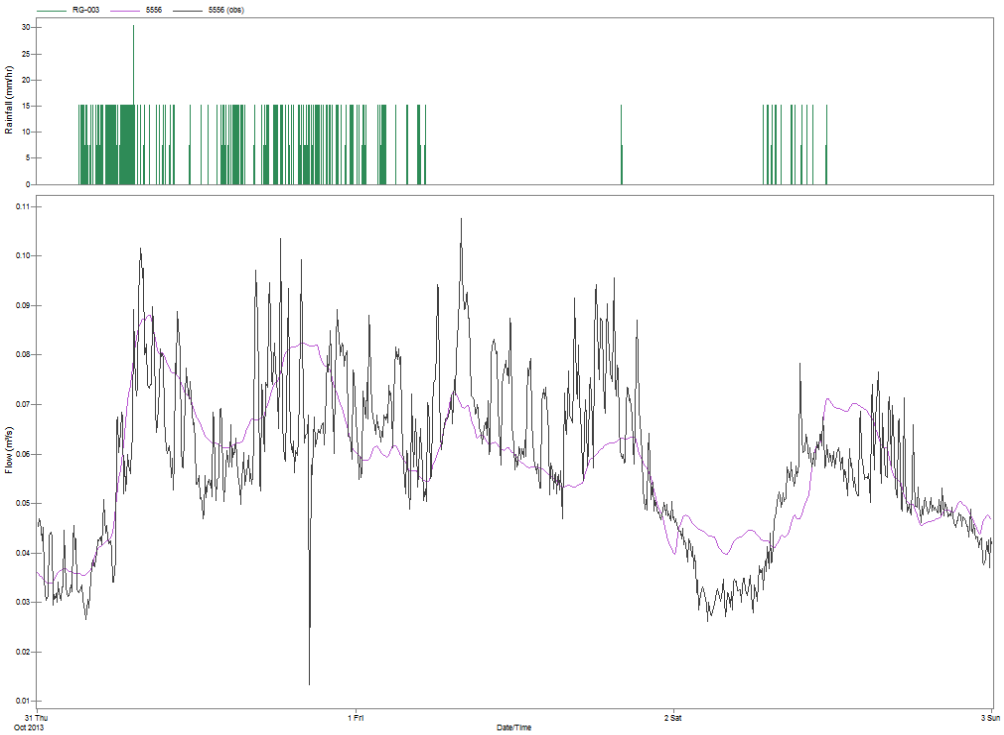
Model Input Parameters

Parameter	1	2	3
R	0.025	0.005	0.001
T	0.21	12.00	24.00
K	28	5	4

R_{total}
3.1%

October 30, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Oct31-Nov2_2013.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
10/30/2013 23:54	72	42.42	30.48	0.108	0.088	0.059	0.058	15160	15050
Difference (%)					-18%		-1%		-1%



1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

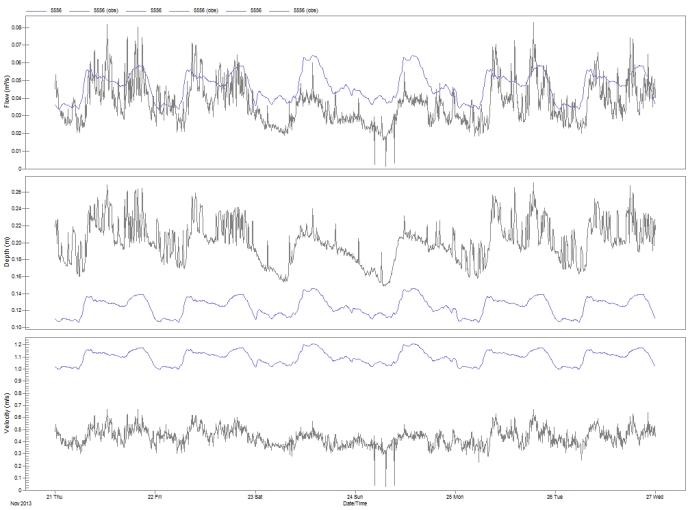
Monitor: FM-014 FWL-22

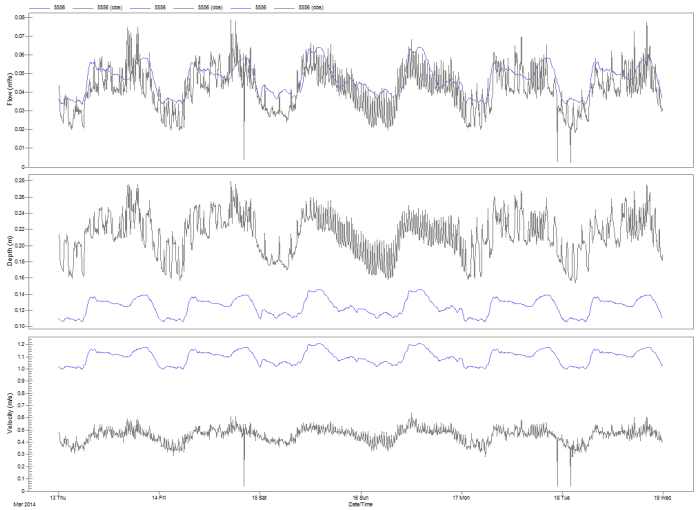
Conduit: 5556

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	November 21-26, 2013				Date	March 13-18, 2014		
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.061	0.059			0.061	0.059		
Base Flow (L/s)	6.21	7.36			6.21	7.36		
Population	10948	10948			10948	10948		
Per Capita (L/c/d)	130	122.0			130	122.0		
Avg. Sewage (L/s)	16.5	15.5			16.5	15.5		
Pipe (mm)	600	600			600	600		
Total Area (ha)	102.0	125.1			102.0	125.1		
Incremental Area (ha)	102.0	125.1			102.0	125.1		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.271	0.146	-0.125	-46%	0.279	0.146	-0.134	-48%
Q_{max} (m^3/s)	0.083	0.064	-0.019	-23%	0.079	0.064	-0.015	-19%
Vol (m^3)	19289	24336	5047	26%	21470	24336	2866	13%
Vel_{max} (m/s)	0.7	1.2	0.5	80%	0.6	1.2	0.6	88%

Graph





1611-11191: Waterloo Sanitary Master Plan

Wet Weather Calibration - Final

Monitor: FM-015 FWL-50

Conduit: 4763

Diameter: 375 mm

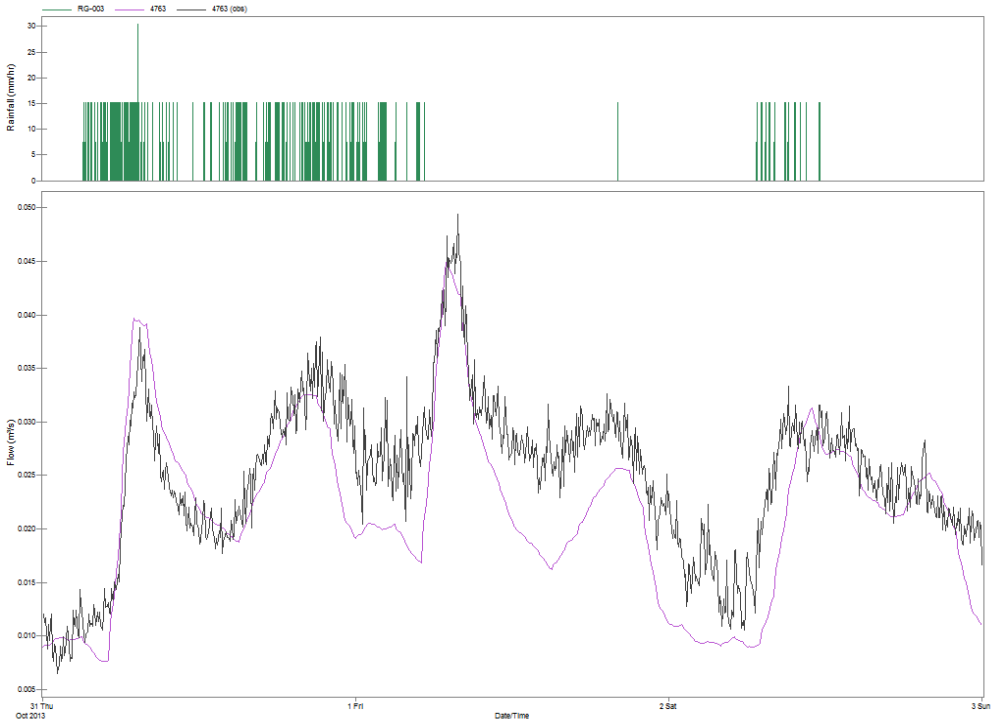
Model Input Parameters

Parameter	1	2	3
R	0.017	0.007	0.001
T	1.00	12.00	24.00
K	20	5	4

R_{total} 2.5%

October 30, 2013 Rainfall Event Model Scenario: Waterloo_WWF_Oct31-Nov2_2013.inp

Reporting Start Date	Reporting Duration (h)	Rainfall Depth (mm)	Peak Intensity (mm/hr)	Observed Max (m^3/s)	Current Max (m^3/s)	Observed Mean (m^3/s)	Current Mean (m^3/s)	Observed Total (m^3)	Current Total (m^3)
10/30/2013 23:54	72.25	42.42	30.48	0.049	0.045	0.025	0.021	6452	5570
Difference (%)					-9%		-14%		-14%



1611-11191: Waterloo Sanitary Master Plan

Dry Weather Calibration - Final

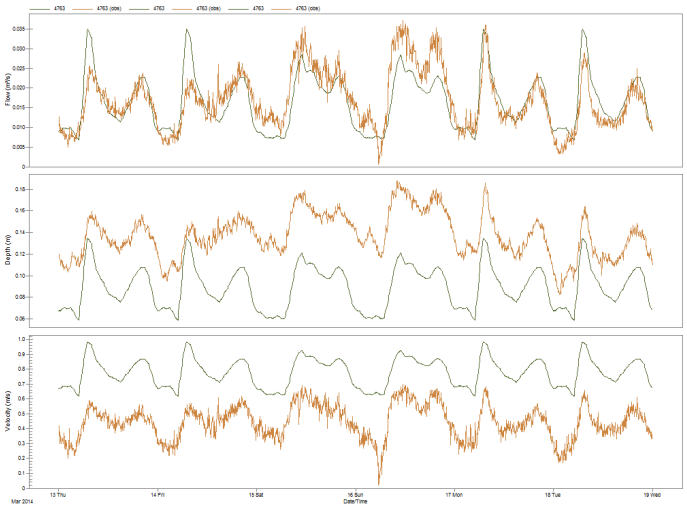
Monitor: FM-015 FWL-50

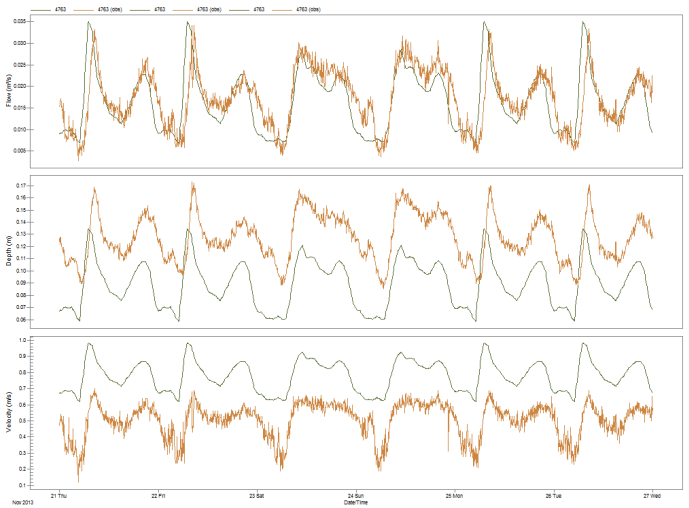
Conduit: 4763

Target %	
D_{max}	-20 to +20%
Q_{max}	-15 to +15%
Vol	-20 to +20%

	Calibration Event				Validation Event			
Date	Mar 13-18, 2014				Date	Nov 21-26, 2013		
Input Parameters	**Observed**	**Simulation**			**Observed**	**Simulation**		
Base Flow (L/s/ha)	0.023	0.023			0.023	0.023		
Base Flow (L/s)	2.96	2.93			2.96	2.93		
Population	5505	5505			5505	5505		
Per Capita (L/c/d)	213	213			213	213		
Avg. Sewage (L/s)	13.5	13.54			13.5	13.54		
Pipe (mm)	375	375			375	375		
Total Area (ha)	131.1	129.7			131.1	129.7		
Incremental Area (ha)	131.1	129.7			131.1	129.7		
Metrics	**Observed**	**Simulation**	**Diff**	**%**	**Observed**	**Simulation**	**Diff**	**%**
D_{max} (m)	0.188	0.135	-0.053	-28%	0.173	0.135	-0.038	-22%
Q_{max} (m^3/s)	0.037	0.035	-0.002	-6%	0.034	0.035	0.001	2%
Vol (m^3)	8834	8534	-300	-3%	8998	8534	-464	-5%
Vel_{max} (m/s)	0.7	1.0	0.3	40%	0.7	1.0	0.3	40%

Graph





1611-11191: Waterloo Master Plan Update

Wet Weather Flow Recalibration/Revalidation Results

Last Updated: 2/11/2015

Monitor		Peak Observed Flow (m^3/s)					Peak Simulated Flow (m^3/s)					% Difference in Peak Flow				
		28-May	28-Jun	4-Jul	20-Sep	30-Oct	28-May	28-Jun	4-Jul	20-Sep	30-Oct	28-May	28-Jun	4-Jul	20-Sep	30-Oct
FWL-4A	FM-002	0.257	0.485	0.599	0.630	0.397	0.484	0.362	0.542	0.667	0.317	88%	-26%	-9%	6%	-20%
FWL-22	FM-014	N/A	N/A	N/A	N/A	0.108	N/A	N/A	N/A	N/A	0.088	N/A	N/A	N/A	N/A	-18%
FWL-50	FM-015	N/A	N/A	N/A	N/A	0.049	N/A	N/A	N/A	N/A	0.045	N/A	N/A	N/A	N/A	-9%

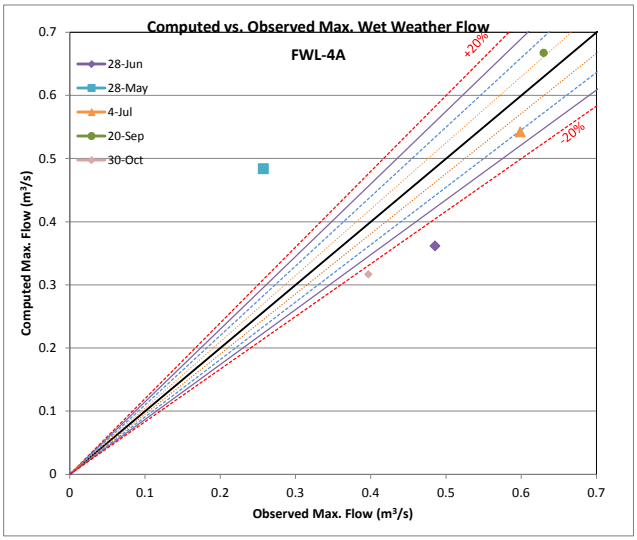
1611-11191: Waterloo Master Plan Update

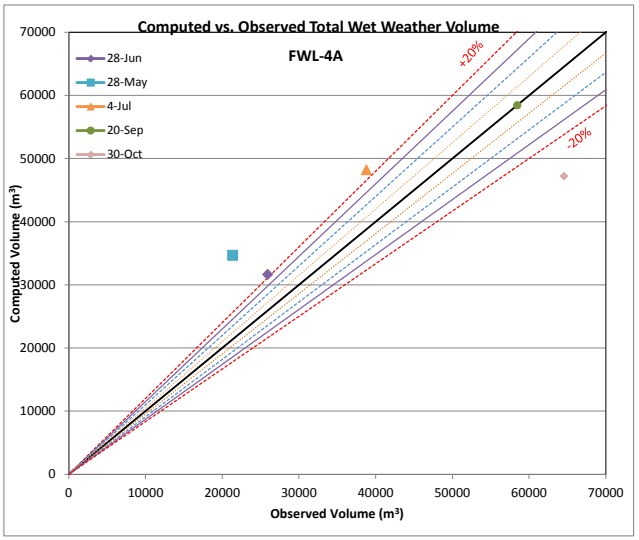
Wet Weather Flow Recalibration/Revalidation Results

Last Updated: 2/11/2015

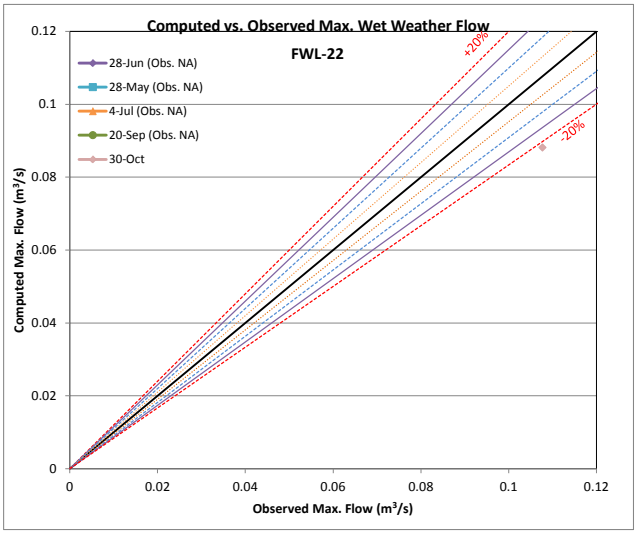
Monitor		Observed Flow Vol. (m^3)					Simulated Flow Vol. (m^3)					% Difference in Flow Volume				
		28-May	28-Jun	4-Jul	20-Sep	30-Oct	28-May	28-Jun	4-Jul	20-Sep	30-Oct	28-May	28-Jun	4-Jul	20-Sep	30-Oct
FWL-4A	FM-002	21360	25910	38800	58470	64540	34680	31650	48230	58440	47230	62%	22%	24%	0%	-27%
GLN-4	FM-003	N/A	N/A	N/A	N/A	15160	N/A	N/A	N/A	N/A	15050	N/A	N/A	N/A	N/A	-1%
LEE-9	FM-004	N/A	N/A	N/A	N/A	6452	N/A	N/A	N/A	N/A	5570	N/A	N/A	N/A	N/A	-14%

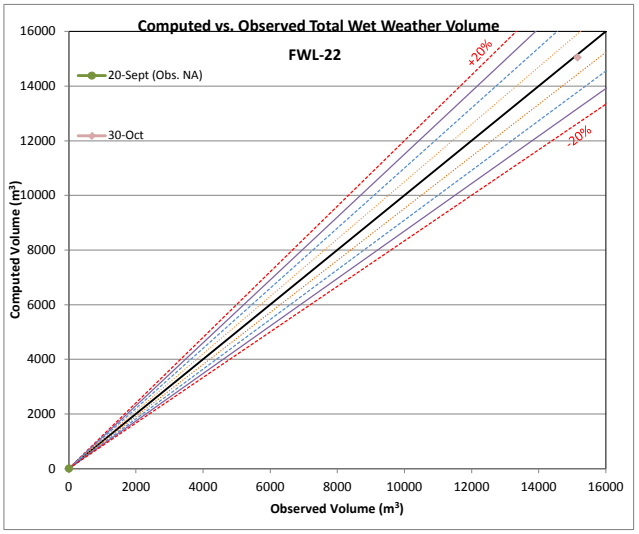
FWL-4A



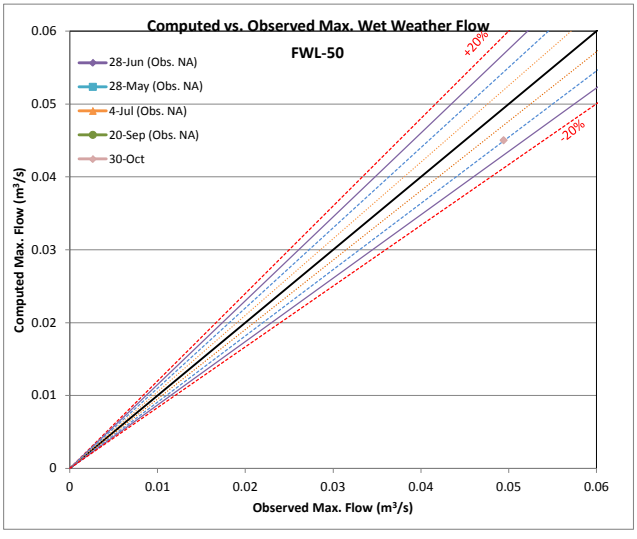


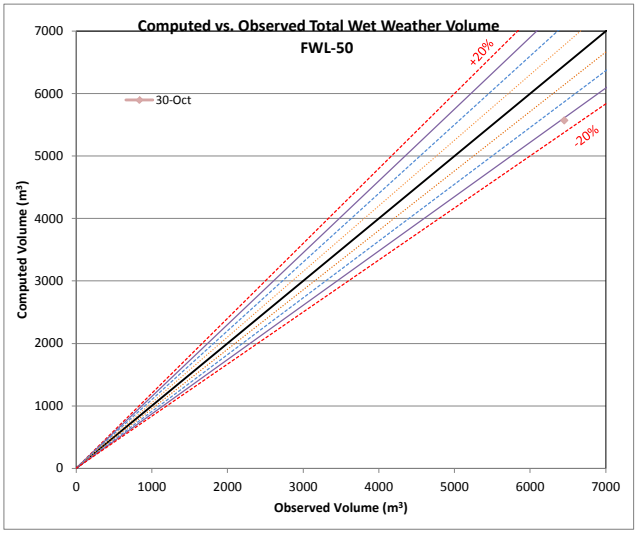
FWL-22





FWL-50





1611-11191: Waterloo Master Plan Update

Dry Weather Flow Recalibration/Revalidation Results

Last Updated: 11-Feb-15

Monitor		Peak Observed Flow (m^3/s)		Peak Simulated Flow (m^3/s)		% Difference in Peak Flow	
		Calibration	Validation	Calibration	Validation	Calibration	Validation
FWL-4A	FM-002	0.265	0.173	0.238	0.237	-10%	37%
FWL-22	FM-014	0.083	0.079	0.064	0.064	-23%	-19%
FWL-50	FM-015	0.083	0.124	0.100	0.106	21%	-15%

1611-11191: Waterloo Master Plan Update

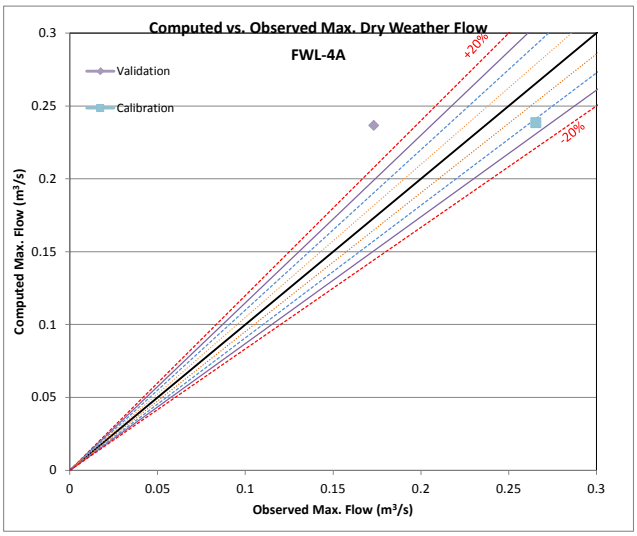
Dry Weather Flow Recalibration/Revalidation Results

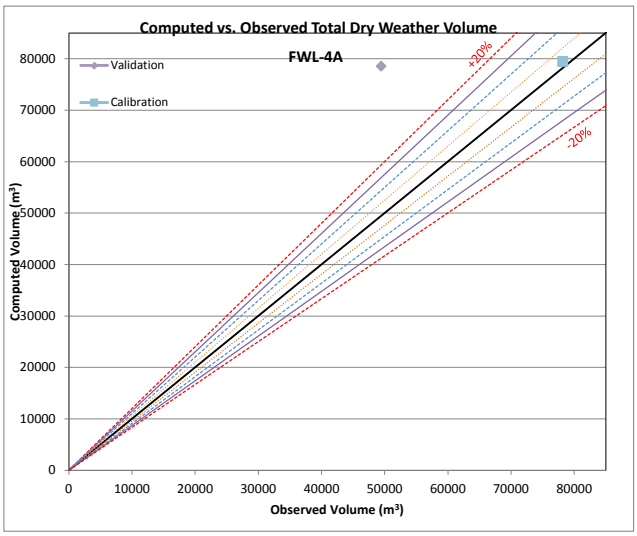
Last Updated: 11-Feb-15

Monitor		Observed Flow Vol. (m^3)		Simulated Flow Vol. (m^3)		% Difference in Flow Volume	
		Calibration	Validation	Calibration	Validation	Calibration	Validation
FWL-4A	FM-002	78187	49457	79493	78568	2%	59%
GLN-4	FM-003	19289	21470	24336	24336	26%	13%
LEE-9	FM-004	8834	8998	8534	8534	-3%	-5%

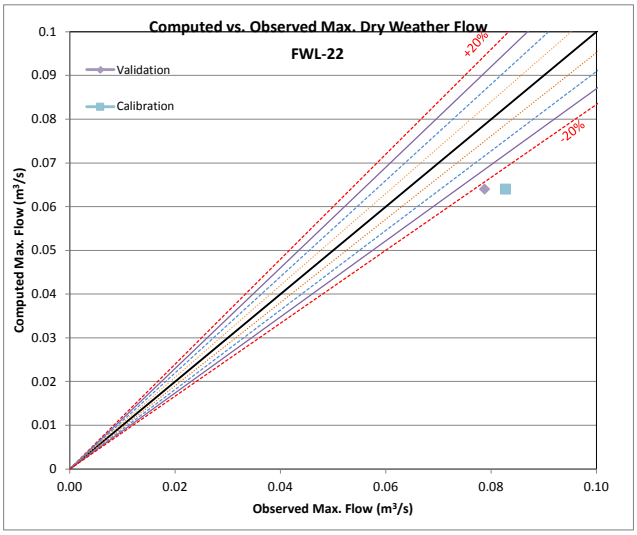
1611-11191: Waterloo Master Plan Update
Dry Weather Flow Recalibration/Revalidation Plots

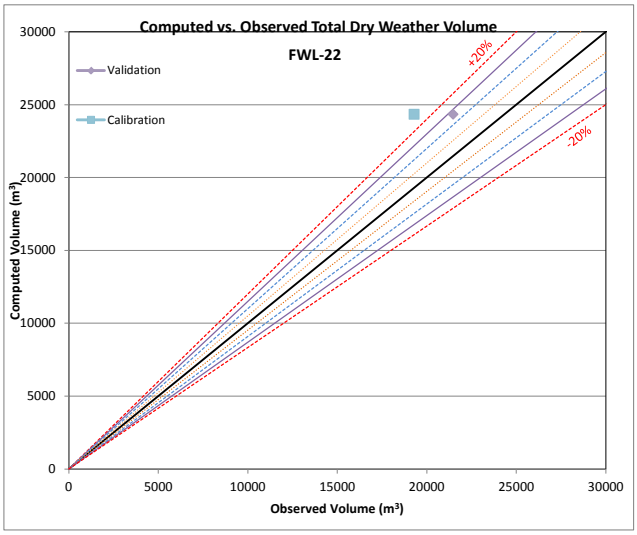
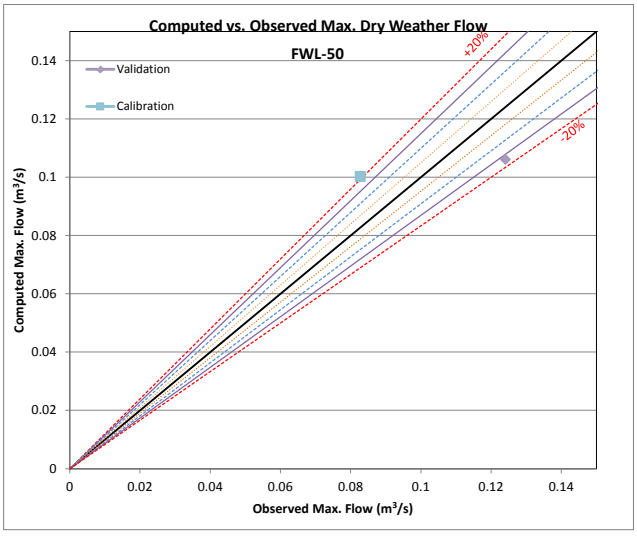
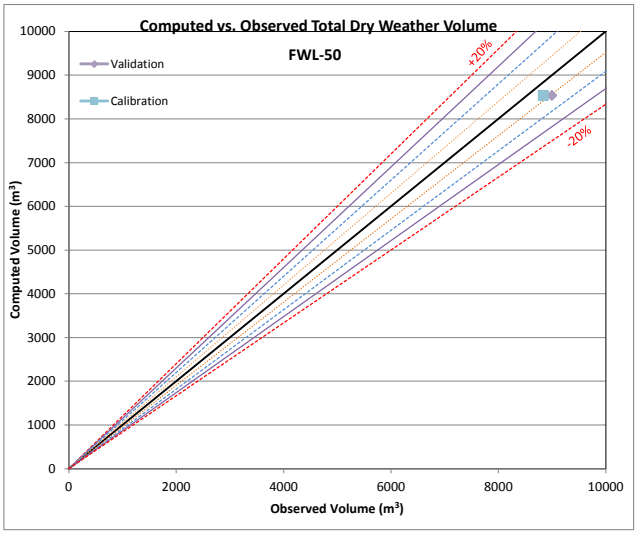
FWL-4A





FWL-22





FWL-50